ECONOMIES OF SCALE IN COMPUTER USE: INITIAL TESTS AND IMPLICATIONS FOR THE COMPUTER UTILITY

Lee L. Selwyn

June, 1970

PROJECT MAC
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Cambridge Massachusetts 02139

ECONOMIES OF SCALE IN COMPUTER USE: INITIAL TESTS AND IMPLICATIONS FOR THE COMPUTER UTILITY*

Abstract

This study is concerned with the existence of economies of scale in the production of data processing and other computing services, and the possible regulatory and public policy implications of such economies.

The rapid development of the technology of computation since the Second World War has raised many questions as to the supervision by public authorities of the use and progress of this technology. A study was initiated by the Federal Communications Commission in 1966 in an effort to consider that Commission's role in the production and distribution of computing services where the use of communications facilities, supplied by regulated carriers, forms an integral part of the computing system. The present investigation is concerned with the production of computing services *per se*; the direction that public policy takes will be greatly dependent upon the nature of the production of computing services, and perhaps secondarily upon the interdependence between computer systems and the communications suppliers.

The relative economies of the use of large computing systems have been known for some time, in terms of the relationship between some measure of the quantity of output of a machine and its cost. Indeed, it is demonstrated here that, when one considers, in addition to the cost of the computer hardware itself, the various categories of operating expenses associated with a computer installation, the relative advantages of large facilities become even more significant.

---

*This report reproduces a thesis of the same title submitted to the Alfred P. Sloan School of Management, Massachusetts Institute of Technology, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1969.

Yet the evidence would seem to indicate that, despite these apparent efficiencies of large systems, the overwhelming majority of installed computers were generally fairly small operations. In an attempt to determine whether actual experience of users was that, all things considered, there were no true economies of large size, an analysis was made of data on nearly 10,000 computers installed at firms in manufacturing industries, using the survival technique, which uses market experience as a basis for studying levels of optimum plant size. The results of this analysis suggested that users did operate computers as if there were significant economies of scale in their use.

None of the evidence, in fact, suggested that even the largest size system available today is the most efficient possible size of "plant"; hence, the key implication for the formulation of regulatory policy toward the computer is that such policy should encourage, to the greatest possible extent, the shared use of large systems by those who require computing services. Those barriers that do exist which tend to mitigate such shared use should be reduced or eliminated. Public utility status would be indicated only if the costs associated with shared computer use - distribution, software development, system overhead and administration - are less than the potential direct savings resulting from use of large systems. This is at least as much a technological problem as it is regulatory; the future of the computer utility concept will thus be dependent upon the degree to which technology can reduce costs in these categories.

ACKNOWLEDGEMENTS

The work reported here was supported in part by Project MAC, an M. I. T. research program sponsored by the Advanced Research Projects Agency, Department of Defense, under Office of Naval Research Contract number Nonr-4102(01). Reproduction of this report, in whole or in part, is permitted for any purpose of the United States Government.

Partial Support was also received under a Dissertation Grant-in-Aid from the National Association of Accountants.

The analyses were made using the Compatible Time Sharing System (CTSS) developed at Project MAC on the IBM 7094. TROLL, an econometric analysis and simulation system available within CTSS, was used for the regression analyses. Additional data reduction procedures were accomplished on the IBM 360/65 operated at the M. I. T. Information Processing Center.

Many of the ideas presented and developed in the course of this work were the result of suggestions made by a number of individuals. My thesis committee, Profs. Paul W. MacAvoy, Malcolm M. Jones and Donald C. Carroll were extremely helpful in making suggestions and directing (and sometimes redirecting) the course of my work. I must also express my thanks to my colleague, Nelson Hanover, for his many suggestions and criticisms.

Dr. Horace J. DePodwin of Rutgers University, with whom I worked on the preparation of the response by the Business Equipment Manufacturers Association to the FCC Computer Inquiry, was a valuable source of advice during the course of this work. Others included James Holmes of BEMA, Benjamin Kessel of Honeywell, Frank J. Rowe of the New England Telephone and Telegraph Company, Barbara Epstein of DePodwin Associates, Profs. F. J. Corbato and Robert M. Fano of Project MAC and the MIT Department of Electrical Engineering, Prof. Manley Irwin of the University of New Hampshire, Prof. John Menge of Dartmouth College, and my colleagues, Lawrence H. Wortzel, H. K. Wu, Y. S. Chang, Earl M. Foster, and John S. Fielden of Boston University.

Special thanks must go to those who provided me with the several sources of empirical data without which the analyses reported here would not have been possible. Patrick J. McGovern and James Peacock of International Data Corporation made available to me the source of data on computer installations which IDC has collected and maintained, and also made themselves available on a number of occasions to help clear up problems that arose from time

to time. My thanks also go to Mr. Richard S. Cook of the General Services Administration, who made available to me the source file for the Federal Government's computer installation inventory. I must also express my gratitude to Mr. Mark Eisner of the MIT Department of Economics, who developed the TROLL System, for providing useful advice during the course of the data analysis phase of this study.

Finally, I must express my sincere appreciation to my wife, Judy, whose encouragement helped see us both through a long graduate program.

TABLE OF CONTENTS

TABLES AND CHARTS

Tables:

Charts:

CHAPTER ONE

COMPUTERS AND PUBLIC POLICY

INTRODUCTION

Much discussion is presently taking place regarding the issue of possible regulation of computer services as a "public utility" in a manner similar to that characteristic of the electric power, gas, transportation and communications industries. This study is concerned with one possible basis for such regulation - the existence of significant economies of scale in the production of computing services.

A general background of the various issues involved is presented in this chapter. Chapter two examines the direct operating cost side of the production of computing services, and concludes that there are definite economies in the use of large size facilities, although various institutional and technological factors may prevent end-users from taking full advantage of them.

In an attempt to determine the extent of economies of scale in practice, an analysis was made of computer usage patterns in manufacturing industries. The results of this study, which are reported in Chapter three, do indeed suggest the existence of noticable economies of scale in the production of computing services. Indeed, it is concluded

that the optimum size of computer plant may be greater than even the largest machines in use today. Hence, Chapter four concludes the study by suggesting that public policy should be directed toward reduction of the barriers that tend to prevent use of larger more efficient systems by groups of individual users. However, it is pointed out that there are costs associated with multi-user sharing of a large system that may not be present when such a system is operated by and for only one user organization. These costs must be less than the advantages associated with the large systems in order not to merely offset an economy with a diseconomy in the use of large facilities.

BACKGROUND OF THE PROBLEM

In November, 1966 the Federal Communications Commission announced that its Common Carrier Bureau was undertaking an extensive inquiry aimed at determining what, if any, interdependencies exist between the computer and communications industries, and to what extent, if any, such interdependence warrants regulatory action by the Commission or some other regulatory body. (1)

The "Computer inquiry," as it is commonly called, was given impetus as a result of several significant developments in the technology of information processing in recent years. Since the Second World War, when military requirements resulted in the first really important innovations in the development of computing machinery, the

extent to which such devices have taken up key positions in the economic, social and political life of this country has been quite remarkable, especially when one considers that all of this happened in less than two decades.

As the computer's role in the nation's life has assumed greater import, so too has the need for sound public policy towards the machine, and its implementation on a fairly general level, become more urgent. Although there is, today, a considerable amount of interest in the problem of public policy formulation covering the technology of data processing, much of it has been stimulated by the aforementioned FCC study. As a result, the questions currently being considered by those studying the overall issues of public policy toward data processing have been those raised by the Commission. (2-6)

The intrinsic importance of the questions raised by the Commission cannot be underrated; however, in a sense they do stem from perhaps the wrong direction. The regulatory implications of the interdependence between computer systems and communications companies forms but one aspect of the overall issue of public policy toward the computer. (Another issue of at least equal importance is the matter of personal privacy protection from potentially uncontrollable computer-based data banks of the Orwellian variety.) Others include such anti-trust matters as company size, market share and marketing practices; such technical issues as

programming language standardization, machine specification and design standardization; and of course the issue of privacy raised by the possibility of the Federal Government installing and maintaining a "National Data Bank" covering all individuals and organizations. The communication issues, as raised by the FCC, do have some particular significance insofar as one key development in computer technology is concerned: the remote access, time-shared computer system. Such facilities provide for simultaneous usage of large computing systems by a number of individual users, often doing a number of individual, and different, things, all connected directly to the computer by telecommunications facilities usually supplied by a communications common carrier.

The intrinsic importance of the time-shared computer is that (a) it has the potential for making available to users of modest means a (possibly) large computer system at a cost that is based upon the quantity of service actually obtained (7); (b) to the extent that there are economies of scale in the production of computing services, the shared use of computing facilities may bring down the average cost of computer usage; (c) extensive use of such systems can replace and to some extent render obsolete some portions of the installed communications plant now operated under exclusive franchise by communications carriers; and (d) because the computer's services may be "piped in" to the end

user's location via communications lines, the limit of possible application areas for such systems becomes bound only by man's imagination.

In a sense, none of these attributes of time-shared computer systems are new to the computer field. A user of modest means could always purchase computing services from a firm specifically established to provide them, or from another user who did maintain his own in-house computing facility. Shared use of large machines might have enabled many individual users to obtain the benefits of the scale economies in the operation of machines of this size. Computers have been slowly replacing many conventional forms of communication, replacing written notes and spoken words with specially designed messages that modify a data base or cause some specific action to be taken. Finally, with the increased experience in the use of computers, there would seem to be virtually no limit, even without remote access, time-shared systems, to which this technology could be applied.

Hence the time-sharing development has not really created any new problems and raised any new questions - it has served to bring several dormant issues out into the open. Time-sharing mainly increases the availability of computing machinery, and as the computer becomes more available, as it enters more areas of life, the concerns over how it should be controlled and regulated multiply.

There are, in fact, two categories of regulatory issues that have been raised. One concerns various operating practices of the computer industry and computer end-users, and includes such issues as technical standardization, personal privacy, sales practices of computer manufacturers, etc. The second set of issues, certainly not unrelated to the first but nonetheless identifiable as a distinct problem area, is the question of possible public utility status for suppliers of computing services, along similar lines as practiced in the natural gas, electric power, transportation and communications industries. The study reported here was principally concerned with the latter group of issues.

NATURAL MONOPOLY AND THE PUBLIC UTILITY CONCEPT

John Stuart Mill observed in 1848 that (a) gas and water service in London could be supplied at lower cost if the duplication of facilities by competitive firms were avoided, and (b) that in such circumstances, competition was unstable and inevitably replaced by monopoly (8). Mill thus noted that, under certain conditions, the forces of market competition would not result in either the lowest possible cost or the best service to the community. The conditions may be met when the production function for a given industry is characterized by significant long-run decreasing average costs, i.e., economies of scale. Where production of goods or services may be accomplished at substantially lower cost if done in large quantities, it is inevitable that larger

sized firms will be able to produce and sell their output at lower cost, thereby driving out smaller producers. If, instead of operating under a competitive environment, the industries characterized by economies of scale were forced to operate under conditions of monopoly, then the potential duplication and waste resulting from competition might be avoided. In its place, however, would be a monopolist who could exact monopoly prices from the community and engage in other monopoly practices. Hence, some substitute for the forces of competition is in order. Such a substitute has historically taken the form of some government regulatory body charged with the responsibility of safeguarding the public interest. Generally, such bodies have permitted the "natural monopoly" to earn only a "reasonable return" on its investment, in exchange for an exclusive franchise to serve the public with whatever type of service it provides.

The existence of substantial economies of scale is not a sufficient condition for regulation, however. One additional test that must be met is that of necessity - the output of the firms in the industry must be necessary to the public good. (An industry that has a decreasing cost production function but does not produce a necessary good or service is, in effect, competing with other industries that produce non-necessary goods or services for the buyers' money, and, as a result, the public does not need to be protected from possible monopolistic practices.) (8,9)

This study has, as its primary objective, the determination of the extent to which the traditional concept of public utility regulation may be applied to the provision of computer services. To this end, the primary emphasis is placed upon the question of the existence of significant economies of scale.

It would be difficult for anyone to deny the fact that computing services are necessary services; they have attained this status over the past two decades by the extent to which computers have taken up important positions in so many aspects of social and business life. If computing services may be more efficiently supplied by a regulated, "natural monopoly" than by free competition, as is the practice today, then public policy must be directed toward the creation of a natural monopoly status for computer services. However, if such economies cannot be demonstrated, than public policy must safeguard the freedom of competition in the provision of such services by preventing any monopoly in part or all of the computer industry from being formed.

THE COMPUTER SERVICE INDUSTRY

The "Computer Service Industry" is defined, for the present study, as consisting of all "plants" that produce computing services. Such plants need not be independent computer service firms, such as service bureaus or datacenters, although these firms certainly form part of the

industry as defined here. All computers, whether operated as in-house facilities by the end-user organization or by firms specifically organized to supply such services to others, constitute the computer service industry.

This "industry" is considered as including all computer service-producing plants because in effect any end-user of such services has, available to him, the option of either purchasing the required services from an outside supplier or producing them with an in-house facility. Under this definition, at the end of 1968 there were some 50,000 plants producing computing services in the United States. (10)

REFERENCES

(1) Federal Communications Commission, "Notice of Inquiry into the Regulatory and Policy Problems Presented by the Interdependence of Computer and Communications Services and Facilities," Docket No. 16979, FCC 66-1004, 8 P&F Radio Reg. 2d 1567-68 (Nov. 9, 1968).

(2) Horace J. DePodwin Associates, Inc. "Major Economic Issues in Data Processing/Data Communications Services," (New York: Business Equipment Manufacturers Association, 1968). Portion of response of BEMA to FCC Notice of Inquiry, op. cit.

(3) Irwin, Manley R. "The Computer Utility," Datamation, November 1967.

(4) Mathison, S. L. and P. M. Walker, "Public Policy Issues Arising from the Interdependence of Computers and Communications," Masters thesis, Sloan School of Management, MIT, 1968.

(5) Baran, Paul, "The Coming Computer Utility - Laissez-faire, Licensing or Regulation," Public Interest, Summer, 1967.

(6) Fano, Robert M., "The Computer Utility and the Community," IEEE International Convention Record, 1967.

(7) Diamond, D. S. and L. L. Selwyn, "Considerations for Computer Utility Pricing Policies," Proceedings of 23rd National Conference, Association for Computing Machinery 1968.

(8) Garfield, P. J. and W. F. Lovejoy, Public Utility Economics, (Englewood Cliffs, N.J.: Prentice-Hall, 1964). p. 15

(9) Bonbright, James C., Principles of Public Utility Rates, (New York: Columbia University Press, 1961).

(10) "Monthly Computer Census," Computers and Automation, March, 1969.

CHAPTER TWO

ECONOMICS OF COMPUTER SYSTEM OPERATION

INTRODUCTION

It has generally been asserted that there are certain economies associated with the use of large size data processing systems. The purpose of the present chapter is to examine the relative validity of the various contentions made, and to provide a basis for an examination of the patterns of computer use in manufacturing industries, the subject of Chapter three.

We consider first the previous work in this field - Grosch's Law and the research by Knight on the subject of computer performance vs. cost. Next, the results of an analysis of cost patterns of computer installations in the Federal Government is presented, with the conclusion that, when one includes in the cost of operating a computing center all cost categories, not just machine rent, the magnitude of the economies of scale become even more pronounced. Finally, this chapter considers several possible bases for (short-run) diseconomies that may exist in the provision of computing services, which may minimize the impact of the scale economies as reflected in the pattern of direct costs.

ECONOMIES OF SCALE IN COMPUTER HARDWARE

In the late 1940's, Herbert Grosch proposed a relationship between hardware cost and quantity of computation that could be provided by the hardware. This relationship, which has since become known as Grosch's Law, states that

$$\text{Computing Power} = C * (\text{ System cost })^2 \qquad (1)$$

where C is a constant determined by the level of technological development.
Thus, according to Grosch's Law, it would be possible to obtain a computer with four times the "power" at only about twice the cost.

Kenneth E. Knight sought to consider the implications of this relationship in light of changes in technology. (1,2) Certainly, it was true that newer computer models were often more costly, and substantially more powerful, than their predecessors. Knight's findings were that indeed Grosch's Law was still valid, even under conditions of changing technology. By holding technology constant by considering all models introduced in any one year seperately, Knight determined that the exponent was more like 2.5 for scientific applications and 3.1 for commercial applications. (2, p. 35).

It is not clear, of course, whether or not the prices of computers reflect costs of development and production, or whether or not the computer manufacturers consciously

establish prices for their products in accordance with some relationship of this type. However, to the extent that there are now a fairly large number of hardware system suppliers, one might be willing to discount any overt pricing decision based upon performance rather than cost. (Although it is certainly valid that, within a single manufacturer's product line price is based upon relative performance, to at least some extent.)

Besides the direct, somewhat measurable economies proposed by Knight, there may be certain other economies associated with relatively large systems that are not generally available in the smaller models. This is a result of the development of the techniques of multiprogramming and multiprocessing. Any given program being executed on a computer will, at various times, require use of different components associated with the computer system. Traditionally, when one component was in use by the program, the others would remain idle. (The computer had a "one-track" mind, concerning itself with but one thing at a time.) However, it is now possible for several programs to be run on a machine simultaneously, either via a batch processing or remote access time-sharing operation. Under such a procedure, when any one program is using one component and leaving the others idle, these might be made available to other programs, thereby increasing overall system throughput. Of course, there are costs associated

with this procedure, and these must be weighed against the benefits. In general, the larger the machine, the greater the opportunity for savings under a multiprogramming environment.

ECONOMIES OF SYSTEM OPERATION

Hardware costs represent, however, only one part of total costs incurred in the course of running a computer installation. Other cost categories include peripheral devices, keypunching and other data collection activities, programming support personnel, system management personnel, physical site facilities, air conditioning, maintenance, magnetic tapes and disk packs, and expendable supplies such as punched cards, continuous forms, and the like. In general, these costs will rise as hardware cost rises, since a larger operation is needed to support a larger size machine. To determine the exact nature of the relationship between computer system rental and total operating costs, we analyzed cost data on 1,039 computer installations in service within the Federal Government, in both civilian and military establishments. Interestingly (and somewhat surprisingly) it was discovered that, at least within the Federal Government, the rate of increase in overall operating expenses is <u>slower</u> than the rate of increase in hardware system rent. This would suggest that, despite the increased staff and operating facilities required to support a large system, and despite the exponentially increasing

capabilities of larger systems, the average total cost per unit of computation decreases even faster when all expenses are considered than when only hardware rent is considered.

The analysis revealed the following relationship between rent (R) and total operating expenses (X):

$$\ln (X) = 1.9016 + .7657 \ln (R) \qquad (2)$$

Table II-1 presents a summary of average rent and operating expenses for Federal Government installations divided into eight size classes. Some of these installations may contain several different computer systems. The curve that was fitted to these data is plotted, along with the actual data points, in Chart II-1.

The same analysis was made for Federal Government installations with two or fewer computer systems, in an attempt to isolate the operating costs of running a single installation. (In installations with two systems, one is most often operated as a satellite of the other, usually larger, system.) Here the rate of decline of total operating expenses versus har#dware system rent was even faster than in the previous case, suggesting again that the number of systems may be of just as much significance as the size of the system in determining the amount of operating expenses required. These results are presented in Table II-2 and Chart II-2. (Details of both regression analyses are presented in Table II-3.)

The direct applicability of the data on computer installations in the Federal Government to commercial, non-government operation may be subject to some question. Indeed, there are several differences in Federal Government accounting practices vis-a-vis commercial practices that may alter the magnitudes of the costs reported. These are considered in somewhat more detail in the Appendix. However, it is quite unlikely that any differences are other than in the magnitudes of the figures involved, and the basic trend that was uncovered from this data is probably quite valid generally.

KNOWN DISECONOMIES IN COMPUTER OPERATION

The cost figures presented by Knight and by the author are deficient in that they generally refer to directly applicable cost categories that are charged directly to computing center operation, and within that to routine operation. In fact, this is not sufficient because the computer directly affects many other categories of costs within an organization.

Certainly, some of these other cost categories ought to have very little to do with the relative size of the computing system, but may be affected by the results, or output, of the computer's operation. However, certain other costs are more directly affected, and these are considered here.

Control over Computer Operations. Many end-users of computer systems consider it essential that they be able to control the activities of the computer installation; hence they demand that the computer they use be an in-house facility. There may be several reasons for this feeling, some of which may have greater validity than others. First, to the extent that the computer is still a novelty in many facets of industrial activity, there is an important element of prestige associated with having one's own system, without having to deal with some outside supplier. Then there is the concern over security of the data files maintained by the machine, and the belief that such security could not be guaranteed were the organization to contract with some other source for computing services. There is also the desire to have the computer available on a priority basis when needed, something which a service bureau might not be able to guarantee. In any event, whatever the validity of these reasons, many end-users have been of the view that, since the cost of the computer was such a small part of total company expenses, and, since the cost of the machine was possibly justified on the basis of perhaps only one application, there was no reason to be concerned about saving some money and sharing a larger machine with other firms, some of whom might even be competitors.

Uniqueness of Applications and Costs of Development General use of large size, more efficient machines is

mitigated by the existence of certain technological and institutional factors in the computer service industry. First, virtually every computer application in existence, and there are perhaps over 100,000 distinct applications in operation, is unique to at least some degree. Even the most common, pedestrian applications, such as payroll accounting, accounts receivable billing and accounts payable processing, are usually designed especially for the end-user firm. Moreover, once a user has committed resources to the development of an application program package for one machine type, he often must amortize this investment over a certain time period, irrespective of other economies of routine operation that he might realize by a switch to some other model. Such a process is often costly and is not done without considerable justification in most instances.

Two opposing forces have been developing that might perhaps modify this situation in time. One is the fact that newly developed applications are often far more complex, and hence far more expensive to implement, than previously existing uses. However, at the same time, new developments in software may make the development of new applications, and the conversion of old ones to different machines, a less arduous task. A new software industry is only now beginning to pass along economies of software development to its clients by, in effect, sharing development costs of a package among several of them. The software firm writes the

basic programs in a fairly machine-independent format, and then implements the program individually on each client's system. In the past, end-users usually wrote their own applications programs from scratch, since there was no easy means of modifying a preexisting program without, in many cases, pirating the programmers from the organization where it was written.

Standardization. There is relatively little of significance in the way of standardization within the computer manufacturing industry. Programs written on one machine will usually not run on a machine of some other type; indeed the program may not even run on another machine of the same type! On the software side, programming languages have achieved some degree of standardization, but the standard is rarely implemented on a widespread basis. A case in point is the ASA Standard FORTRAN IV language specifications, which seek to provide a uniform language for all FORTRAN programs. This standard has, in practice, been used as a minimum, rather than an optimum, by the manufacturers and users. Many have developed their own versions of FORTRAN IV that include additional capabilities. The effect of this is that a program written in the expanded version cannot be run on another system that does not use the same expanded version; the adoption of a standard here has been virtually worthless.

It does not follow, however, that this is necessarily undesirable. Adoption of a firm standard by the computer field would necessarily act as an impediment to innovation and development. In the FORTRAN example just cited, many of the "added" features are quite useful and important; they might not have been introduced at all if the standard was firmly adhered to. The value of setting standards must be weighed against the value of innovative freedom. In an industry so characterized by innovation, adoption of firm standards would seem to be premature at this time. Hence, the diseconomies associated with the necessity for a user to adhere to his present machine as long as possible will still be present for some time to come.

Diseconomies of Sharing. It was suggested earlier that there were advantages, as well as costs, associated with the technique of multiprogramming a large computer. These "costs of sharing" arise in both technical and operational ways, some of which may never actually show up on any user's books. Technically, additional hardware is required to support a multiprogramming environment. The cost of such hardware may often exceed the cost of the basic processing capability. In another study (3) it was learned, for example, that the "sharing overhead" components in one major time-sharing system then under development would be about 65% of total hardware cost, not to mention such additional cost factors as communications facilities, and the cost of

writing the software for the system, perhaps as high as $6 million.

From the operational standpoint, the user of a remotely located computing facility must incur certain costs in order to gain access to the machine. If it is a time-shared, remote access system, he must contract for communications services from a common carrier, and lease a remote access terminal device. If the service involved is a batch processing system, the user must arrange for pickup and delivery of his jobs, and must bear the cost of any inconvenicnce that may result from some delay in transit.

CONCLUSION

From the foregoing, we conclude that although there are certain obvious and significant economies in the operation of a computing facility that would tend to make large systems far more efficient than small ones. We have also observed that there are certain factors that may negate any such efficiencies.

Thus we must ascertain the extent of actual economies of scale in practice. To accomplish this, an analysis was made of acquisition practices of firms in the manufacturing industries to determine whether they were acting as if the economies did outweigh the diseconomies, or vice versa. Although few of the installations studied operate in a time-sharing type of environment, the analysis does present a basis for assessing the nature of demand for computing

services in manufacturing industries, based upon the presently existing structure of costs for such services. If economies of scale exist under the present technology, then the more widespread use of shared facilities will serve to increase the efficiency with which this equipment is used. The results of this analysis are the subject of the next chapter.

REFERENCES

(1) Knight, Kenneth E., "Changes in Computer Performance," _Datamation_, September 1966, pp. 40-54.

(2) Knight, Kenneth E., "Evolving Computer Performance," _Datamation_, January 1968, pp. 31-35.

(3) Diamond, D. S. and L. L. Selwyn, (1968), _op. cit._

TABLE II-1
RENT AND EXPENSES FOR ALL FEDERAL GOVERNMENT INSTALLATIONS

NOBS	.G.RENT.LE.		MEAN RENT	SIGMA RENT	MEAN TOTEXP	SIG TOTEXP	MN RNT/EXP	SIG RNT/EXP
113	0	2	1.373	.527	8.232	10.547	.317	.220
227	2	5	3.291	.859	17.904	13.831	.295	.213
126	5	10	7.365	1.471	30.749	43.469	.381	.227
185	10	20	14.065	2.746	45.795	31.790	.385	.169
134	20	40	28.433	5.459	97.422	92.618	.408	.195
96	40	70	52.745	8.252	135.200	57.117	.450	.177
38	70	100	85.125	8.110	198.998	91.045	.504	.190
120	100	9999	268.226	240.941	483.989	353.124	.568	.178

TABLE II-2
RENT AND EXPENSES FOR INSTALLATIONS WITH 2 OR FEWER COMPUTERS

NOBS	.G.RENT.LE.		MEAN RENT	SIGMA RENT	MEAN TOTEXP	SIG TOTEXP	MN RNT/EXP	SIG RNT/EXP
104	0	2	1.381	.522	7.383	7.215	.319	.219
219	2	5	3.270	.838	17.263	13.008	.299	.214
107	5	10	7.386	1.414	29.659	46.166	.381	.205
127	10	20	13.201	2.416	45.643	37.088	.386	.177
59	20	40	28.751	5.682	76.501	37.759	.443	.174
27	40	70	52.213	7.231	109.929	40.550	.523	.156
9	70	100	86.287	7.683	179.861	105.705	.605	.226
5	100	9999	227.367	204.001	271.767	190.158	.785	.182

TABLE II-3
RESULTS OF REGRESSION ANALYSES

```
1. LOG(SYSTOT) = A0+A1*LOG(SYSRNT) $,

NOB = 8                 NOVAR = 2
RANGE      1     1      8     1
REGR4

RSQ =      0.9975      SER =      0.0718       SSR =       0.0309
F(1/6) = 2437.8990       DW(0) =      3.0744

COEF                          VALUE      ST ER      T-STAT

A1                           0.7657     0.0155    49.3751
A0                           1.9016     0.0521    36.4693
```

a. All Federal Government Installations

```
1. LOG(SYSTOT) = A0+A1*LOG(SYSRNT) $,

NOB = 8                 NOVAR = 2
RANGE      1     1      8     1
REGR4

RSQ =      0.9924      SER =      0.1143       SSR =       0.0784
F(1/6) =  784.3572       DW(0) =      1.9961

COEF                          VALUE      ST ER      T-STAT

A1                           0.7050     0.0252    28.0064
A0                           1.9344     0.0837    23.1157
```

b. Installations with 2 or Fewer Computers

LOG TOTAL EXPENSES VS. LOG RENT

HORIZONTAL - LSYSTO VERTICAL - LSYSRN

1 TO 8 = Y

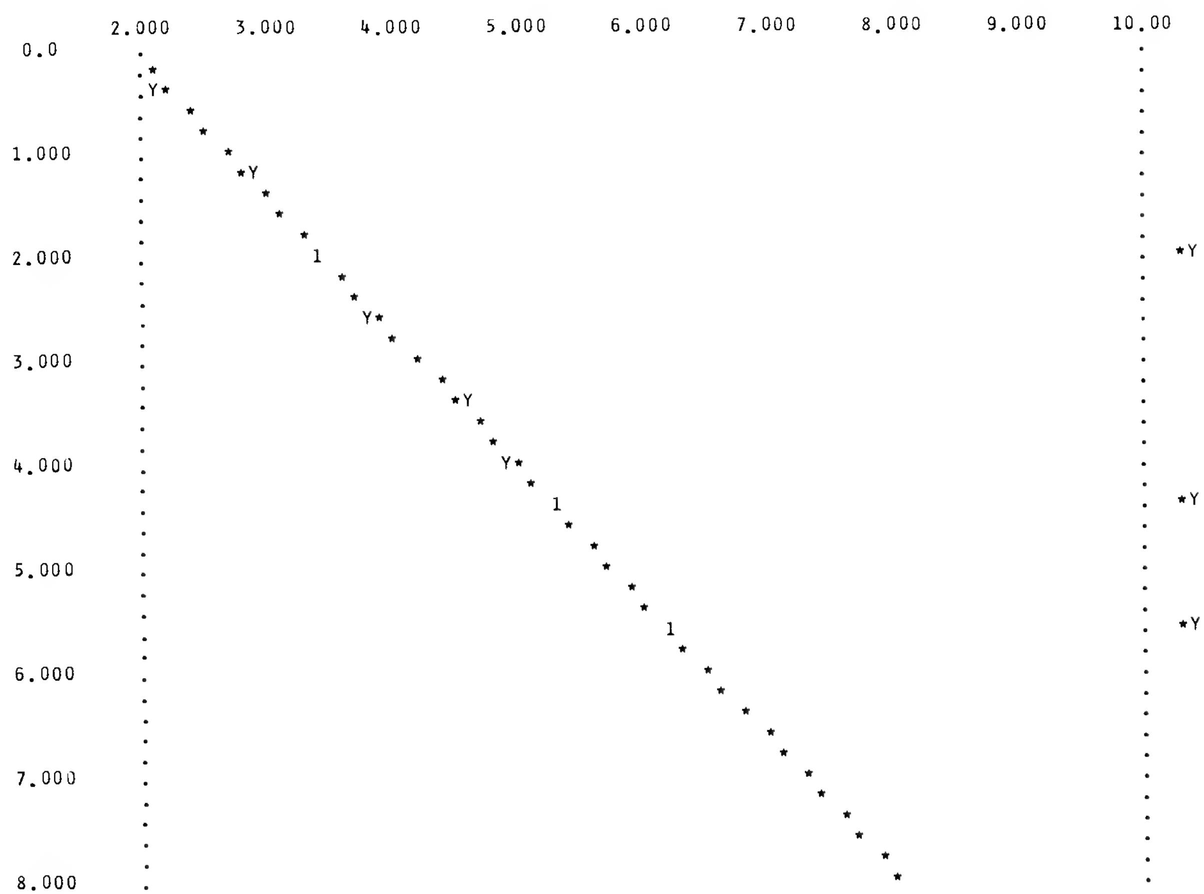

CHART II-1

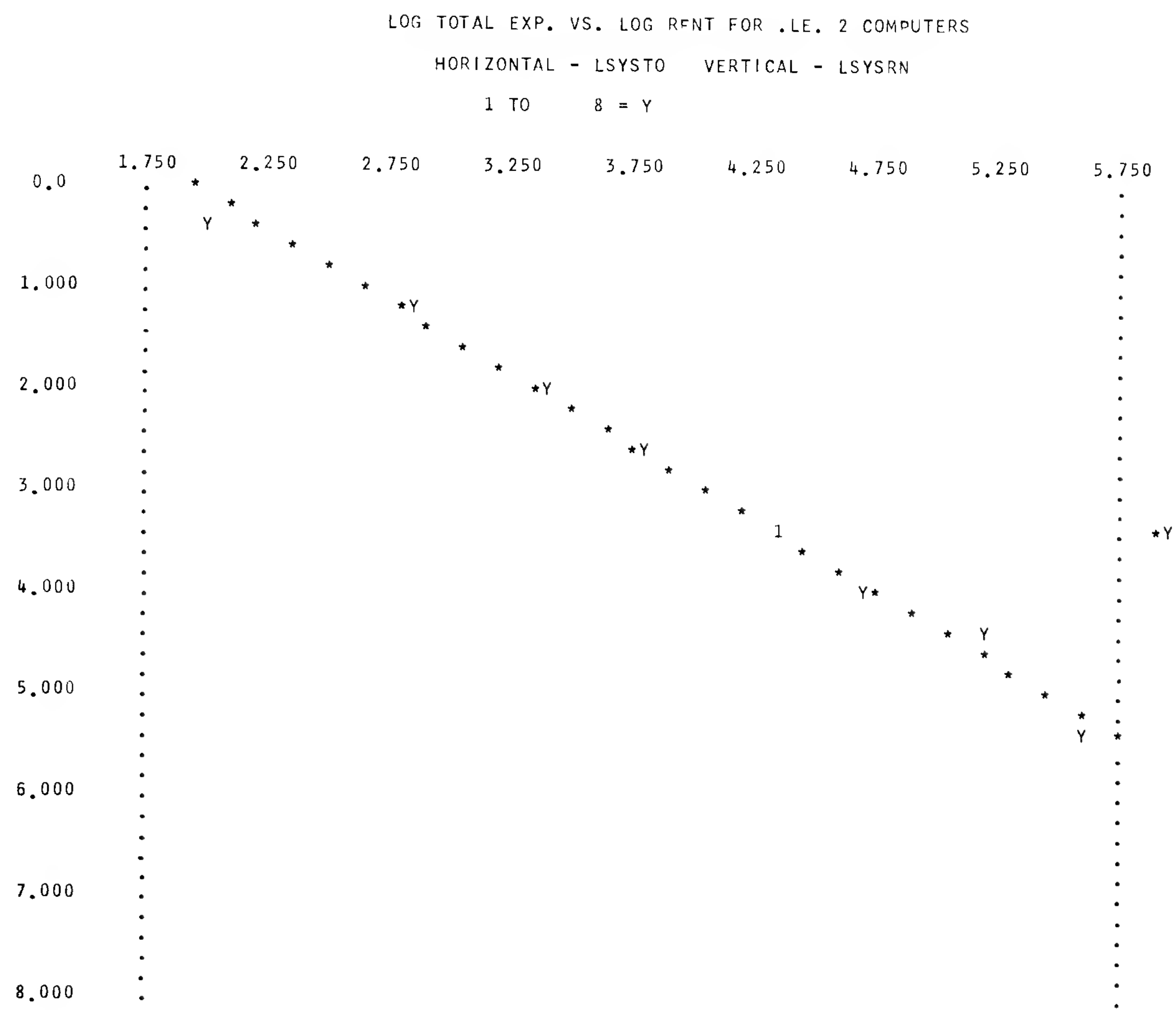
LOG TOTAL EXP. VS. LOG RENT FOR .LE. 2 COMPUTERS
HORIZONTAL - LSYSTO VERTICAL - LSYSRN
1 TO 8 = Y
1.750
2.250
2.750
3.250
3.750
4.250
4.750
5.250
5.750
0.0
1.000
2.000
3.000
4.000
5.000
6.000
7.000
8.000

CHART II-2

CHAPTER THREE

OPTIMUM PLANT SIZE IN THE COMPUTER SERVICE INDUSTRY

THE SURVIVAL PRINCIPLE

The last chapter considered the determination of relative economies of scale in the provision of computing services by an analysis of relevant cost areas and by consideration of known short-run diseconomies which might act as detriments to obtaining the fullest cost advantages of the use of large scale computer systems. The present chapter considers the question of economies of scale by attempting to determine the optimum plant size in the computer service industry. A plant is defined as a single computer system, although several such systems might be in operation within a single installation.

In considering the question of optimum plant size, Stigler (1) noted that:

> An efficient size of firm . . . is one that meets any and all problems the entrepreneur actually faces: strained labor relations, rapid innovation, government regulation, unstable foreign markets, and what not. This is, of course, the decisive meaning of efficiency from the viewpoint of the enterprise. . . .
>
> The survivor technique proceeds to solve the problem of determining the optimum plant size as follows: Classify the firms in an industry by size, and calculate the share of industry output coming from each class over time. If the share of a given class falls, it is relatively inefficient, and in general is more inefficient the more rapidly the share falls. (1, p. 56.)

Under this view, it should be possible to determine the relative efficiency of plants of various sizes merely by studying the existence and survival patterns of plants of various sizes in an industry. In the long run, only the most efficient firms, which presumably are those of relatively optimum size (assuming a continuous production function) would survive in a competitive market. Indeed, Stigler observes that

> Not only is the survivor technique more direct and simpler than the alternative techniques for the determination of the optimum size of firm, it is also more authoritative. Suppose that the cost, rate of return, and technological studies all find that within a given industry the optimum size of firm is one which produces 500 to 600 units per day, and that costs per unit are much higher if one goes outside this range. Suppose also that most of the firms in the industry are three times as large, and that those firms which are in the 500 to 600 unit class are rapidly failing or growing to a larger size. Would we believe that the optimum size was 500 to 600 units? Clearly not: an optimum size that cannot survive in rivalry with other sizes is a contradiction . . .(1, p. 56).

In another study, Simon and Bonini (2) used this principle to disclose the fact that in general, industry cost curves were "J" shaped, that is, above a certain minimum size of firm, expansion would take place along a constant cost portion of the long-run average cost curve and that, for most relevant size magnitudes, the theoretical upturn in what is considered to be a "U" shaped curve will not occur. The Simon-Bonini model was based upon the observation that over time there was no greater p roportionate change in size among firms at various points

in the spectrum of firm sizes. If an industry were experiencing economies of scale (i.e., expansion was taking place along the decreasing cost portion of the industry cost curve) then firms of relatively large size would have an increased probability of survival than their smaller competitors. Hence, under such cost conditions, we would expect, over time, to observe a greater proportionate change in size of large firms than of small firms.

T. R. Saving, in yet another application of the survival technique (3) suggested that there was some value in considering only the size distribution of plants at some single instant in time, thus, in effect, making the (perhaps heroic) assumption that the existing distribution of plants is optimum (3, p. 578). Certainly, this implies that any movements or trends toward optimum plant size in an industry are reflected in the existing structure of that industry; that a "snapshot" is sufficient to indicate some direction of movement. The survival technique is used, in the present study, in this manner, since the rapid rate of technological change in the computer field would render comparisons of plant sizes in different periods of little value.

Saving also concluded that "the greater the size of the market, the larger will be the optimum size (of plant) because it is the size of the market which allows a plant to be large enough to take advantage of all the economies of production which are available." He further notes that "by

size of market we refer to the size of the market in which the plant competes, and not the industry, since it is the market for the individual plant's output which determines the extent to which that plant may take advantage of existing economies of scale." (3, p. 587). Weiss (5, p. 253), came to a similar conclusion by demonstrating that for any given industry the percentage of total capacity within any market (region) that was in plants of at least minimum efficient size increased with the size of the market. (i.e., the larger the market, the more the potential economies of scale were realized.)

In the computer service industry, as we have defined it, the "market" that is served by an individual "plant" (i.e., computer) is most often restricted to the firm which uses the computer's services as an input to its production process. Hence, by segmenting the computer service industry into its individual markets, we may examine the relative economies of scale in the industry as a whole by determining the nature of the effect upon optimum computer size of the specific market in which it operates.

This was accomplished by classifying the individual plants in the computer service industry into groups according to the specific (manufacturing) industry that each machine serves. This, of course, assumes that all firms in a manufacturing industry possess essentially identical production functions. Further, if we assume, as Bain (4)

and Simon and Bonini (2, *op. cit.*) have suggested, that industry cost curves are usually J-shaped such that in general constant costs exist above some minimum critical point, then by assumption the quantity of computing service demanded by a firm in any one industry should vary in direct proportion to its size, along a linear homogeneous production function for the (manufacturing) firm.

THE SURVIVAL PRINCIPLE APPLIED TO COMPUTER SERVICES

The operating cost data considered in Chapter two might lead one to expect that no computer save for the very largest is efficient, and that the prudent user will always obtain the largest system he can. However, this does not seem to be true in practice. In an attempt to determine what does occur in practice, the survival technique was applied to data on nearly 10,000 computer systems in manufacturing industries. Stigler suggests that survival *over time* is the key variable to be observed. However, as already observed, with the rapid rate of technological change in the computer industry, time series would not indicate any meaningful pattern, since the production functions in different years might not be strictly comparable (or even remotely similar!). As an alternative to studying survival patterns over time, usage patterns across a number of industries, each of which has its own characteristic structure, were analyzed.

If there were no actual economies of scale in the production of computer services, then we might expect the size pattern of systems serving firms within a particular industry to reflect the structure of that industry. Further, proportionate changes in industry characteristics should result in a change of like proportion in the typical size of a computer installed within a firm in the industry. If economies of scale do exist, then the relationship between industry structure and computer size pattern would be less definite. Also, changes in industry structure should result in less than proportional changes in computer size, indicating that because smaller installations are less efficient to operate, relatively large systems are required to serve industries characterized by small firms.

Assuming linear homogeneous production functions for firms in manufacturing industries, then

$$d = \omega s_i$$

where d is the quantity of computing service demanded by a firm of size s_i in industry i, and ω is a constant. The Bain and Simon-Bonini findings lend credibility to this function for outputs as related to direct inputs. Outputs here are given by firm size s_i, since we measure size in values of product shipments; but the input here, d, is very indirect; computer service is part of administrative, research, and process control functions, none of which approach "labor" as a direct input. But all three of these

indirect services are used to explain the <u>existence</u> of firms; that is, analysts of organizations place responsibility for limits on organization (or firm) size on the decreasing returns to scale of services in these three categories. We assume only constant returns, as a cautious first step in our analysis; decreasing returns would add to the strength of the findings below.

Thus, if p_i is the average size of a computing plant in industry i, then

$$d = \alpha p_i^{\gamma}$$

where α is a constant and $\gamma \leq 1.0$ if no economies of scale exist and $\gamma > 1.0$ if they do. That is, if economies of scale exist, then a less than proportionate change in average size of computing plant will be required for any change in quantity of computing services demanded, d. This relationship may be rewritten as

$$p_i = \frac{1}{\alpha} d^{\beta} = As_i^{\beta} \qquad \text{for } \beta = \frac{1}{\gamma}$$

where $\beta < 1.0$ under conditions of economies of scale.

Thus, if firm size is increased by some factor k, then kp < kd. We would expect a proportionate change in power as a result of a change in firm size only if no economies of scale are present. However, where such economies do exist, then the smaller firms are already using larger machines than they might be doing under conditions of constant costs, such that the magnitude of the increase in computer size is not as great as that in firm size.

MEASURES OF PLANT SIZE IN THE COMPUTER SERVICE INDUSTRY

In order to test this hypothesis, it was necessary to find a set of variables that would characterize the structure of the user industry and another group to characterize the structure of installed computer systems within the user industry.

Six variables were selected to describe the user industry: industry size, industry growth, industry concentration in the four largest firms, number of establishments in the four largest (and most important) firms, labor intensiveness, and capital intensiveness. (The appendix describes each of these more fully and presents, in Table A-1, a summary of these variables for the 119 industries studied.)

The variables used to characterize the structure of computer sizes were average rent, average total expenses, and average power. These are summarized, for each industry, in Table A-2.

Average rent. Average rent was computed by using, as mean rental values in each of eight size classes of computer systems, the values obtained from an analysis of the cost patterns in the Federal Government installations (see Tables A-2, A-3, A-4). Although a more valid method might have been to determine the actual rent for each computer installed, the data were not sufficient to develop such price determinations. However, considering the number of

systems studied, any variations can be expected to be averaged out over all systems. Hence, the use of the experience within the Federal Government is probably a fairly good estimator of actual average costs.

Average total expenses. Once again, the data on computer systems in the manufacturing industries was not sufficient to permit any determination of operating expenses. However, the results of the analysis of the Federal Government experience were used and are believed to reasonably estimate non-government experience. It should be noted, however, that certain expense categories are not included in the Federal Government's direct computer system operating costs that are usually figures by nongovernment users. However, it is believed that these are probably a fixed percentage of non-rent expenses, and will not materially affect the results obtained in the present application.

Average Power. A measure of the productive capacity of computer systems is provided by Knight's indicies of computing power, discussed earlier (and in the Appendix).

Although rent and operating expenses would seem to be measures of system cost, they are also measures of system size, just as number of employees, sales, kilowatt hours used per month, etc., are all measures of plant or firm size. Use of the power variable, however, provides the best measure for change in productive capacity which we assert

should be proportional to a change in any structural characteristics of the user industry if computing costs are constant. However, the change in one of the cost variables will provide a more direct measure of the change in relative expenditure on the typical system. If this change is approximately in the same proportion as a change in industry structure, then clearly there are no economies of scale. However, to the extent that this change is less than the like change in the industry structure, then there would seem to be certain efficiencies of large scale systems that are indeed being enjoyed by firms of larger size.

CONSTRUCTION OF THE MODEL

Linear regression analysis was used to test for relationships between any of the six industry variables and the three computer size variables just decribed. In the case of industry growth, labor intensiveness, and capital intensiveness, there was no significant relationship between any of these and any of the three computer size descriptors. Hence, these three variables were discarded from further analysis. The most significant relationship was found in a model whose independent variables consisted of the natural logarithms of industry size, concentration ratio, and number of establishments in the four largest firms. The three multiple regression equations were, then

$$\ln R = a_0 + a_1 \ln Q + a_2 \ln T + a_3 \ln E \qquad (1)$$

$$\ln X = b_0 + b_1 \ln Q + b_2 \ln T + b_3 \ln E \qquad (2)$$

$$\ln P = c_0 + c_1 \ln Q + c_2 \ln T + c_3 \ln E \qquad (3)$$

where

R = average computer rent

X = average total computer operating expenses

P = average computing power

Q = industry size

T = ratio of size of four largest firms to industry size

E = number of establishment in four largest firms.

a_i, b_i, c_i are regression coefficients.

In effect, the three independent variables, in a non-logarithmic form, form a measure of average plant size in the four largest, and most important, firms in the industry:

$$\text{Average establishment size} = \frac{QT}{E} \qquad (4)$$

The results of these regressions are given in Table III-1. A plot of the logarithm of average plant size against each of the three computer size variables is provided in Charts III-1, 2, and 3.

DISCUSSION OF THE MODEL

The three equations used are transformations of the hypothesized relationship, which is non-linear. Hence, each of these equations could be written

$$P = e^{c_0} Q^{c_1} T^{c_2} E^{c_3} \qquad (5)$$

Since, from Table III-1, $c_1 \approx -c_3$, we may rewrite equation (5) as

$$P = e^{c_0} \left(\frac{Q}{E}\right)^{\beta_P} T^{c_2} \qquad (6)$$

where $c_1 \approx \beta_P \approx -c_3$.

If there were no economies of scale, then both β_P and c_2 would be approximately equal to one, such that any change in average plant size in the user industry would result in a proportionate change in average computer size. However, the results of the regression analysis, as shown in Table III-1, indicate that in fact β_P is approximately 0.4, and c_2 slightly less than 0.7, indicating that there apparently are economies of scale in computing services, and that these economies are most pronounced when average establishment size is changed.

Turning next to the other two cost-related measures of computer size, we find that, for average system rent, β_R = approximately 0.15, and a_2 is approximately .26; in the case of average total expenses, β_X is about 0.095, and b_2, about 0.17. Once again, economies of scale are indicated, especially with respect to average establishment size.

However, the cost-related measures would seem to suggest highly significant economies: If average establishment size is doubled, the average cost of a computer increases by 2**0.095 times, or by only about 10%. Average rent would increase by about 14%.

EXAMINATION OF THE RESIDUALS

Table III-2 presents a summary of the actual and estimated values of average rent for the 119 industries studied. In an attempt to explain at least some of the variation from the model, the subject industries were classified into three groups, depending upon the nature of the applications to which computers had been used in that industry. Table III-3 summarizes this analysis. In general, the model seemed to overestimate the average rent in industries with significant analysis types of applications. These include such activities as engineering design, simulation, job-shop scheduling, mathematical programming, statistical studies, and what not. In the case of industries with process control applications, such as machine operation monitoring, computer typesetting, etc., the model seemed to underpredict the average size of the computer systems installed. The third class included all systems where business applications were predominant, and relatively little analysis or control activities were taking place. The original model seemed to be fairly accurate for this type of industry. Using this same grouping, the

original model was re-run in an effort to determine whether there were any differences in the coefficients, and hence elasticities, when the installations with non-business applications were treated seperately. The purpose here was to isolate those groups of users whose industry production function requires that they make a different _type_ of use of computing devices than most industrial users. A determination of differences in the regression line based upon application area would suggest that the degree to which economies of scale are present in any instance is, to at least some extent, determined by the nature of the service being obtained from the equipment. Table III-3 presents the results of this analysis and indicated that, although there were some small changes, the original conclusions are in no way invalidated.

CONCLUSION

The empirical data suggest that users of computing equipment are behaving as if there were significant economies of scale in the use of such devices. There seems to be a general tendency for users to acquire larger systems than their firm or plant size would indicate is required. A doubling of average establishment size results in only about a 35% increase in the average power of computer installations in the industry, far less of an increase in the two cost measures - machine rent and total operating expenses.

Further, only about 40% of the variation in computer system size could be explained by variations in industry structure. Even when some cognizance was taken of the specific application areas to which computer were used in the subject industries, the relative proportion of the variation that could be explained by the industry structure was not materially altered.

From this, one may only conclude that the decision as to which size machine to use is based upon factors other than the straight quantity requirement for service. Companies do tend to obtain systems that exceed their requirements, because they are substantially cheaper to run, on an average unit of processing basis. What is done with the excess capacity is not clear from this data; there is a developing market in excess computer capacity (within the last two years several new firms have been organized to provide brokerage services in this market).

If there are apparently economies of scale in the provision of computing services, one must then inquire as to what changes might be made to the economic environment of the computer service industry to promote greater efficiency of computer usage. This question is considered in the next, and concluding, chapter of this study.

REFERENCES

(1) Stigler, George J., "The Economies of Scale," J. Law and Economics, (1, October 1958), pp. 54-71.

(2) Simon, Herbert A., and Charles P. Bonini, "The Size Distribution of Business Firms," American Economic Review, XLVIII, (September, 1958), pp. 607-617.

(3) Saving, T. R.,"Estimation of Optimum Size of Plant by the Survivor Technique," Quarterly Journal of Economics, (LXXV:4, November, 1961), pp. 569-607.

(4) Bain, Joe S., Barriers to New Competition, (Cambridge, Mass.: Harvard University Press, 1956)

(5) Weiss, Leonard W., "The Survival Technique and the Extent of Suboptimal Capacity," Journal of Political Economy, (LXXII:3, June, 1964)

TABLE III-1
RESULTS OF REGRESSION ANALYSES

ALL 119 INDUSTRIES

1. LOG(AVGRNT) = A0+A1*LOG(INDSIZ)+A2*LOG(CONCEN)+A3*LOG(ESTAB) $,

NOB = 119 NOVAR = 4
RANGE 1 1 119 1
REGR4

RSQ = 0.3665 SER = 0.2670 SSR = 8.1988
F(3/115) = 22.1815 DW(0) = 2.1211

COEFF	VALUE	ST ER	T-STAT
A1	0.1585	0.0398	3.9789
A0	2.9057	0.3050	9.5253
A2	0.2611	0.0396	6.6026
A3	-0.1408	0.0330	-4.2631

2. LOG(AVGEXP) = B0+B1*LOG(INDSIZ)+B2*LOG(CONCEN)+B3*LOG(ESTAB) $,

NOB = 119 NOVAR = 4
RANGE 1 1 119 1
REGR4

RSQ = 0.3664 SER = 0.1751 SSR = 3.5278
F(3/115) = 22.1712 DW(0) = 2.0545

COEF	VALUE	ST ER	T-STAT
B1	0.0988	0.0261	3.7816
B0	4.7507	0.2001	23.7416
B2	0.1740	0.0259	6.7088
B3	-0.0912	0.0217	-4.2099

3. LOG(AVGPOW) = C0+C1*LOG(INDSIZ)+C2*LOG(CONCEN)+C3*LOG(ESTAB) $,

NOB = 119 NOVAR = 4
RANGE 1 1 119 1
REGR4

RSQ = 0.3440 SER = 0.7602 SSR = 66.4561
F(3/115) = 20.1027 DW(0) = 2.1500

COEF	VALUE	ST ER	T-STAT
C1	0.4702	0.1134	4.1460
C0	5.2613	0.8685	6.0580
C2	0.6764	0.1126	6.0069
C3	-0.4036	0.0940	-4.2927

r sortx ind3
W 1107.8

Table 111-2: Actual And Predicted Values - All 119 Industries

Rank	SIC	Y	YFIT	RESIDU	PCT-ERR	NCOMP	NAME OF INDUSTRY	SIZE	CONC	ESTAB	BUS	ANAL	CNTRL
1	2086	3.6109	4.3065	-.6956	-16.15	27	Bottled and Canned Soft Drinks	2735	14	77	24	0	0
2	3442	3.8286	4.3730	-.5444	-12.45	22	Metal Door, Sash, and Trim	1397	10	11	12	3	6
3	3391	4.1589	4.7168	-.5579	-11.83	33	Iron and Steel Forgings	1273	31	7	20	0	2
4	3731	4.2767	4.7568	-.4801	-10.09	28	Ship Building and Repairing	2339	42	19	22	2	0
5	3674	4.3944	4.8736	-.4792	-9.83	73	Semiconductors	1124	51	5	7	12	3
6	2631	4.1744	4.5975	-.4231	-9.20	18	Paperboard Mills	2853	27	33	13	0	4
7	2013	4.0604	4.4568	-.3964	-8.89	27	Meat Processing Plants	2502	16	29	23	0	0
8	2711	4.1431	4.5404	-.3973	-8.75	207	Newspapers	5520	14	29	107	2	67
9	2431	3.9890	4.3660	-.3770	-8.63	17	Millwork Plants	1345	9	9	13	0	2
10	3317	4.2047	4.5977	-.3930	-8.55	10	Steel Pipe and Tube	1072	26	10	7	0	2
11	3742	4.4308	4.8264	-.3956	-8.20	15	Railroad and Street Cars	1696	50	11	6	1	3
12	2111	4.6444	5.0584	-.4140	-8.18	27	Cigarettes	2860	81	9	19	0	1
13	3241	4.0943	4.4321	-.3378	-7.62	31	Cement, Hydraulic	1253	30	56	20	2	6
14	2971	4.3567	4.7114	-.3546	-7.53	33	Confectionary Products	1681	24	6	27	0	2
15	3441	4.1109	4.4146	-.3037	-6.88	42	Fabricated Structural Steel	2602	14	32	26	5	4
16	3443	4.2905	4.6026	-.3121	-6.78	43	Boiler Shop Products	2323	28	27	22	11	4
17	3351	4.4427	4.7617	-.3190	-6.70	27	Copper Rolling and Drawing	2846	43	24	21	0	6
18	2752	3.9890	4.2722	-.2832	-6.63	18	Printing, Lithographic	2791	5	13	16	0	1
19	2328	4.1431	4.4256	-.2824	-6.38	18	Work Clothing	1052	28	42	13	0	2
20	2051	4.1271	4.4049	-.2778	-6.31	45	Bread and Related Products	5007	25	232	29	1	5
21	2042	4.2195	4.4970	-.2775	-6.17	41	Prepared Animal Feeds	4438	23	85	27	0	0
22	2824	4.6540	4.9587	-.3047	-6.15	13	Organic Fibers, Noncellulosic	1992	85	14	7	3	0
23	2653	4.1109	4.3467	-.2358	-5.42	10	Corrugated Shipping Containers	2891	18	100	8	0	1
24	3562	4.5326	4.7303	-.1977	-4.18	45	Ball and Roller Bearings	1399	56	23	16	2	13
25	3585	4.6250	4.8078	-.1828	-3.80	48	Refrigeration Machinery	2713	34	10	27	0	4
26	3429	4.5951	4.7709	-.1758	-3.68	39	Hardware, N.E.C.	2544	38	14	20	0	11
27	2751	4.3820	4.5454	-.1634	-3.59	72	Printing, Except Lithographic	3202	14	15	47	1	10
28	3069	4.4543	4.6173	-.1629	-3.53	52	Rubber Products, N.E.C.	3139	22	21	34	0	4
29	2026	4.2767	4.4278	-.1512	-3.41	39	Fluid Milk	7435	23	250	30	0	0
30	2011	4.5530	4.7138	-.1599	-3.39	106	Meat Slaughtering Plants	15069	27	91	71	0	3

Rank	SIC	Y	YFIT	RESIDU	PCT-ERR	NCOMP	NAME OF INDUSTRY	SIZE	CONC	ESTAB	BUS	ANAL	CNTRL
31	2818	4.7274	4.8841	-.1567	-3.21	120	Organic Chemicals, N.E.C.	6541	46	28	34	11	9
32	3717	4.9558	5.1112	-.1553	-3.04	443	Motor Vehicles and Parts	45630	79	135	199	26	42
33	2851	4.4067	4.5427	-.1359	-2.99	67	Paints and Allied Products	2970	23	38	47	4	2
34	3941	4.4308	4.5651	-.1343	-2.94	30	Games and Toys	1157	22	10	25	0	3
35	3694	4.7707	4.8874	-.1167	-2.39	13	Engine Electrical Equipment	1342	72	11	9	1	1
36	3291	4.6347	4.7476	-.1129	-2.38	11	Abrasive Products	1016	56	14	7	0	1
37	2815	4.6634	4.7758	-.1123	-2.35	26	Intermediate Coal Tar Products	1483	52	15	13	2	3
38	2432	4.3307	4.4314	-.1007	-2.27	17	Veneer and Plywood Plants	1700	24	51	10	0	0
39	2221	4.5218	4.6155	-.0937	-2.03	18	Weaving Mills, Synthetic	2241	40	48	12	0	3
40	2841	4.7707	4.8663	-.0957	-1.97	28	Soap and other Detergents	2396	72	25	23	0	1
41	3321	4.5643	4.6382	-.0739	-1.59	39	Gray Iron Foundries	2728	27	23	20	3	3
42	3544	4.2047	4.2723	-.0676	-1.58	21	Special Dies and Tools	2218	5	10	14	1	1
43	2899	4.4427	4.5066	-.0640	-1.42	33	Chemical Preparations, N.E.C.	1322	20	15	16	4	2
44	3531	4.7958	4.8612	-.0654	-1.34	63	Construction Machinery	3768	45	17	36	0	10
45	3352	4.7875	4.8415	-.0540	-1.12	16	Aluminum Rolling and Drawing	3100	65	33	28	0	5
46	3545	4.4659	4.5147	-.0487	-1.08	17	Machine Tools and Accessories	1230	20	13	15	0	1
47	2253	4.5326	4.5809	-.0483	-1.05	24	Knit Outerwear Mills	1273	14	4	20	3	0
48	3548	4.5433	4.5851	-.0418	-.91	26	Metalworking Machinery, N.E.C.	1148	25	11	20	2	1
49	3312	4.9416	4.9836	-.0420	-.84	353	Blast Furnaces and Steel Mills	21193	49	57	112	7	47
50	3011	4.8598	4.8960	-.0362	-.74	109	Tires and Inner Tubes	3716	71	32	72	4	5
51	3861	4.9836	5.0154	-.0318	-.63	67	Photographic Equipment	3286	67	10	28	4	4
52	3612	4.7449	4.7632	-.0183	-.38	40	Transformers	1053	66	18	18	6	6
53	3611	4.6250	4.6415	-.0165	-.36	111	Electric Measuring Instruments	1020	36	13	43	21	28
54	2511	4.4188	4.4318	-.0130	-.29	32	Wood Furniture Not Upholstered	2423	12	10	23	0	3
55	3356	4.7274	4.7326	-.0052	-.11	16	Rolling and Drawing, N.E.C.	1051	46	11	10	2	2
56	2082	4.7362	4.7336	.0026	.05	40	Malt Liquor	2700	39	23	30	1	1
57	3821	4.5433	4.5403	.0030	.07	54	Mechanical Measuring Devices	1429	21	14	32	2	7
58	2037	4.5433	4.5306	.0127	.28	31	Frozen Fruits and Vegetables	1885	24	27	24	1	1
59	3357	4.7185	4.7053	.0132	.28	28	Nonferrous Wire Drawing, Etc.	3711	39	41	19	1	5
60	2327	4.4773	4.4624	.0149	.33	13	Separate Trousers	1042	20	16	11	0	0
61	3522	4.8598	4.8313	.0285	.59	166	Farm Machinery and Equipment	4332	45	25	78	6	20
62	2032	4.8675	4.8328	.0348	.72	19	Canned Specialities	1457	63	14	13	0	0
63	3661	4.9836	4.9464	.0372	.75	159	Telephone, Telegraph Apparatus	2467	94	24	57	8	14
64	2834	4.7958	4.7551	.0407	.86	105	Pharmaceutical Preparations	4432	24	13	61	11	1
65	2842	4.6250	4.5850	.0400	.87	20	Polishes and Sanitation Goods	1029	30	14	16	0	1
66	3433	4.5109	4.4699	.0409	.92	50	Heating Equipment, Except Electric	1167	16	11	24	2	7
67	3561	4.7095	4.6588	.0507	1.09	32	Pumps and Compressors	2151	27	15	17	2	6
68	3651	5.0039	4.9478	.0561	1.13	97	Radio and TV Receiving Sets	4092	48	11	63	2	10
69	3079	4.3820	4.3284	.0536	1.24	58	Plastics Products, N.E.C.	4658	8	39	43	1	5
70	3411	4.7362	4.6782	.0580	1.24	27	Metal Cans	2631	71	113	11	1	1

R16.350+7.850

Table 111-2 (CONTINUED)

RANK	SIC	Y	YFIT	RESIDU	PCT-ERR	NCOMP	NAME OF INDUSTRY	SIZE	CONC	ESTAB	BUS	ANAL	CNTRL
71	2231	4.7185	4.6596	.0589	1.26	57	Weaving, Finishing Mills, Wool	1167	56	32	37	1	4
72	3481	4.4067	4.3463	.0604	1.39	16	Fabricated Metal Products, N.E.C.	1300	13	21	10	1	1
73	3566	4.6821	4.6179	.0642	1.39	51	Power Transmission Equipment	1314	25	10	33	1	5
74	3541	4.7005	4.6336	.0669	1.44	64	Metal-Cutting Machine Tools	1826	22	10	33	6	13
75	3323	4.6052	4.5359	.0693	1.53	25	Steel Foundries	1279	22	14	13	1	2
76	2821	4.8122	4.7338	.0784	1.66	84	Plastics Materials and Resins	3532	32	21	52	6	0
77	2052	4.7875	4.6968	.0906	1.93	16	Biscuits, Crackers, and Cookies	1327	59	31	12	0	1
78	2024	4.4886	4.3900	.0987	2.25	33	Ice Cream and Frozen Desserts	1142	33	84	27	0	1
79	2341	4.4427	4.3447	.0980	2.25	27	Women's and Children's Underwear	1042	15	22	20	0	3
80	3613	4.7622	4.6500	.1122	2.41	41	Switchgear and Switchboards	1549	52	41	26	5	5
81	2311	4.5951	4.4831	.1120	2.50	30	Men's and Boys' Suits and Coats	1850	17	19	16	0	8
82	2085	4.8122	4.6923	.1199	2.55	29	Distilled Liquor, Except Brandy	1332	55	28	20	0	0
83	3559	4.6347	4.5090	.1258	2.79	44	Special Industry Machinery, N.E.C.	1731	10	5	21	6	10
84	3642	4.6634	4.5315	.1319	2.91	19	Lighting Fixtures	1544	18	12	16	0	3
85	3461	4.6052	4.4747	.1305	2.92	55	Metal Stampings	3756	11	19	36	0	9
86	3452	4.6052	4.4570	.1482	3.32	30	Bolts, Nuts Rivets and Washers	1662	18	23	23	1	3
87	2621	4.7707	4.6038	.1668	3.62	134	Paper Mills, Except Building	4805	24	45	84	3	15
88	3519	5.0304	4.8433	.1871	3.86	58	Internal Combustion Engines	2052	52	13	27	6	8
89	2099	4.6347	4.4617	.1730	3.88	22	Food Preparations, N.E.C.	2206	26	64	17	1	0
90	2731	4.8752	4.6891	.1861	3.97	126	Books, Publishing and Printing	1996	20	6	79	3	8
91	2871	4.8442	4.6592	.1850	3.97	12	Fertilizers	1183	34	12	9	1	0
92	2911	5.0876	4.8840	.2036	4.17	120	Petrolium Refining	18742	32	45	43	19	2
93	2023	4.6634	4.4725	.1909	4.27	19	Condensed and Evaporated Milk	1100	45	80	12	0	1
94	3599	4.5539	4.3587	.1951	4.48	23	Misc. Machinery	2865	6	10	14	3	4
95	3621	4.9200	4.7083	.2117	4.50	141	Motors and Generators	2289	48	35	66	27	14
96	2033	4.7185	4.5014	.2171	4.82	65	Canned Fruits and Vegetables	3216	24	62	51	0	0
97	2321	4.6540	4.4361	.2179	4.91	27	Men's Dress Shirts and Nightwear	1348	25	41	19	0	0
98	2281	4.6540	4.4278	.2261	5.11	13	Yarn Mills, Except Wool	1479	19	28	9	1	1
99	2041	4.7707	4.5348	.2358	5.20	34	Flour Mills	2345	31	56	24	1	1
100	2512	4.6052	4.3720	.2332	5.33	21	Wood Furniture, Upholstered	1250	15	22	14	0	2
101	3722	5.2523	4.9736	.2787	5.60	80	Aircraft Engines and Parts	4572	58	15	18	18	3
102	2721	5.1299	4.8481	.2818	5.81	104	Periodicals	2718	28	5	55	0	26
103	3679	4.9488	4.6669	.2818	6.04	158	Electronic Components, N.E.C.	4002	22	19	00	46	19
104	3622	5.0304	4.7428	.2876	6.06	42	Industrial Controls	1049	50	12	19	5	5
105	3141	4.6913	4.4204	.2709	6.13	64	Shoes, Except Rubber	2650	26	108	40	0	7
106	2844	5.0876	4.7899	.2977	6.22	71	Toilet Preparations	2431	40	14	58	0	0
107	2211	4.8828	4.5866	.2962	6.46	72	Weaving Mills, Cotton	3562	30	57	40	5	12
108	2335	4.5109	4.2322	.2787	6.59	23	Dresses	2508	8	40	18	0	1
109	3634	5.0499	4.7334	.3164	6.68	43	Electric Housewares and Fans	1128	50	14	22	3	9
110	3662	5.0689	4.7344	.3345	7.07	214	Radio, TV Communications Equipment	7563	24	28	92	45	15

R 16.350+7.850

Table 111-2 (CONTINUED)

RANK	SIC	Y	YFIT	RESIDU	PCT-ERR	NCOMP	NAME OF INDUSTRY	SIZE	CONC	ESTAB	BUS	ANAL	CNTRL
111	2641	4.8442	4.5200	.3242	7.17	33	Paper Coating and Glazing	1383	28	28	15	9	2
112	2643	4.7536	4.4253	.3283	7.42	11	Bags, Except Textile Bags	1359	23	38	6	0	0
113	3221	5.0173	4.6491	.3682	7.92	22	Glass Containers	1207	59	40	10	0	3
114	3721	5.5910	5.1805	.4105	7.92	455	Aircraft	9000	67	9	91	86	14
115	2819	4.9273	4.5530	.3742	8.22	134	Inorganic Chemicals, N.E.C.	3845	29	75	57	19	0
116	3494	4.8040	4.4323	.3717	8.39	49	Valves and Pipe Fittings	2209	13	20	33	2	5
117	2421	4.7449	4.3219	.4231	9.79	52	Sawmills and Planing Mills	3391	11	54	39	0	0
118	3729	5.3982	4.7744	.6238	13.07	127	Aircraft Equipment, N.E.C	3781	26	11	37	39	23
119	3569	5.4205	4.6257	.7948	17.18	43	General Industry Machines, N.E.C.	1024	21	5	19	8	2

R 16.350+7.850

Table 111-2 (CONTINUED)

TABLE III-3a
RESULTS OF REGRESSION ANALYSES

93 INDUSTRIES WITH MAINLY BUSINESS DATA PROCESSING APPLICATIONS

1. LOG(AVGRNT) = A0+A1*LOG(INDSIZ)+A2*LOG(CONCEN)+A3*LOG(ESTAB) $,

NOB = 93 NOVAR = 4
RANGE 1 1 93 1
REGR4

RSQ = 0.4305 SER = 0.2279 SSR = 4.6236
F(3/89) = 22.4293 DW(0) = 2.1672

COEFF	VALUE	ST ER	T-STAT
A1	0.1682	0.0384	4.3830
A0	2.5770	0.3069	8.3963
A2	0.2634	0.0381	6.9135
A3	-0.0652	0.0335	-1.9488

2. LOG(AVGEXP) = B0+B1*LOG(INDSIZ)+B2*LOG(CONCEN)+B3*LOG(ESTAB) $,

NOB = 93 NOVAR = 4
RANGE 1 1 93 1
REGR4

RSQ = 0.4001 SER = 0.1584 SSR = 2.2336
F(3/89) = 19.7826 DW(0) = 2.1305

COEF	VALUE	ST ER	T-STAT
B1	0.1068	0.0267	4.0036
B0	4.5444	0.2133	21.3026
B2	0.1736	0.0265	6.5566
B3	-0.0461	0.0233	-1.9801

3. LOG(AVGPOW) = C0+C1*LOG(INDSIZ)+C2*LOG(CONCEN)+C3*LOG(ESTAB) $,

NOB = 93 NOVAR = 4
RANGE 1 1 93 1
REGR4

RSQ = 0.3765 SER = 0.6978 SSR = 43.3331
F(3/89) = 17.9141 DW(0) = 2.1855

COEFF	VALUE	ST ER	T-STAT
C1	0.4715	0.1175	4.0134
C0	4.7656	0.9396	5.0719
C2	0.7033	0.1166	6.0302
C3	-0.2728	0.1024	-2.6628

TABLE III-3b
RESULTS OF REGRESSION ANALYSES

13 INDUSTRIES WITH MORE THAN
25% ANALYSIS APPLICATIONS

1. LOG(AVGRNT) = A0+A1*LOG(INDSIZ)+A2*LOG(CONCEN)+A3*LOG(ESTAB) $,

```
NOB  =  13              NOVAR  =  4
RANGE      1     1    13     1
REGR4

RSQ  =     0.4513     SER  =      0.4554      SSR  =      1.8664
F(3/9)  =     2.4680     DW(0)  =      1.6657
```

COEF	VALUE	ST ER	T-STAT
A1	0.2566	0.2080	1.2339
A0	2.9351	1.2433	2.3607
A2	0.2374	0.2401	0.9888
A3	-0.3650	0.1618	-2.2559

2. LOG(AVGEXP) = B0+B1*LOG(INDSIZ)+B2*LOG(CONCEN)+B3*LOG(ESTAB) $,

```
NOB  =  13              NOVAR  =  4
RANGE      1     1    13     1
REGR4

RSQ  =     0.5029     SER  =      0.2662      SSR  =      0.6378
F(3/9)  =     3.0353     DW(0)  =      1.6718
```

COEF	VALUE	ST ER	T-STAT
B1	0.1504	0.1216	1.2369
B0	4.6786	0.7268	6.4369
B2	0.1926	0.1404	1.3725
B3	-0.2201	0.0946	-2.3268

3. LOG(AVGPOW) = C0+C1*LOG(INDSIZ)+C2*LOG(CONCEN)+C3*LOG(ESTAB) $,

```
NOB  =  13              NOVAR  =  4
RANGE      1     1    13     1
REGR4

RSQ  =     0.5009     SER  =      1.0615      SSR  =     10.1405
F(3/9)  =     3.0113     DW(0)  =      1.4121
```

COEF	VALUE	ST ER	T-STAT
C1	0.8665	0.4848	1.7876
C0	5.1936	2.8981	1.7920
C2	0.3645	0.5596	0.6513
C3	-1.0278	0.3771	-2.7254

TABLE III-3c
RESULTS OF REGRESSION ANALYSES

13 INDUSTRIES WITH MORE THAN 25%
PROCESS CONTROL APPLICATIONS

1. LOG(AVGRNT) = A0+A1*LOG(INDSIZ)+A2*LOG(CONCEN)+A3*LOG(ESTAB) $,

NOB = 13 NOVAR = 4
RANGE 1 1 13 1
REGR4

RSQ = 0.4514 SER = 0.2680 SSR = 0.6465
F(3/9) = 2.4680 DW(0) = 1.1661

COEF	VALUE	ST ER	T-STAT
A1	0.2445	0.2160	1.1317
A0	2.8487	1.6645	1.7115
A2	0.2122	0.1267	1.6752
A3	-0.2660	0.1126	-2.3630

2. LOG(AVGEXP) = B0+B1*LOG(INDSIZ)+B2*LOG(CONCEN)+B3*LOG(ESTAB) $,

NOB = 13 NOVAR = 4
RANGE 1 1 13 1
REGR4

RSQ = 0.4494 SER = 0.1737 SSR = 0.2716
F(3/9) = 2.4484 DW(0) = 1.2563

COEF	VALUE	ST ER	T-STAT
B1	0.1016	0.1400	0.7258
B0	5.1397	1.0788	4.7644
B2	0.1286	0.0821	1.5666
B3	-0.1619	0.0730	-2.2184

3. LOG(AVGPOW) = C0+C1*LOG(INDSIZ)+C2*LOG(CONCEN)+C3*LOG(ESTAB) $,

NOB = 13 NOVAR = 4
RANGE 1 1 13 1
REGR4

RSQ = 0.2216 SER = 0.9107 SSR = 7.4636
F(3/9) = 0.8540 DW(0) = 0.9387

COEF	VALUE	ST ER	T-STAT
C1	0.7677	0.7339	1.0460
C0	2.9378	5.6556	0.5194
C2	0.6205	0.4304	1.4419
C3	-0.3848	0.3825	-1.0060

LOG AVERAGE RENT VS. LOG ESTABLISHMENT SIZE

HORIZONTAL - LOGRNT VERTICAL - ESTSIZ

1 TO 119 = Y

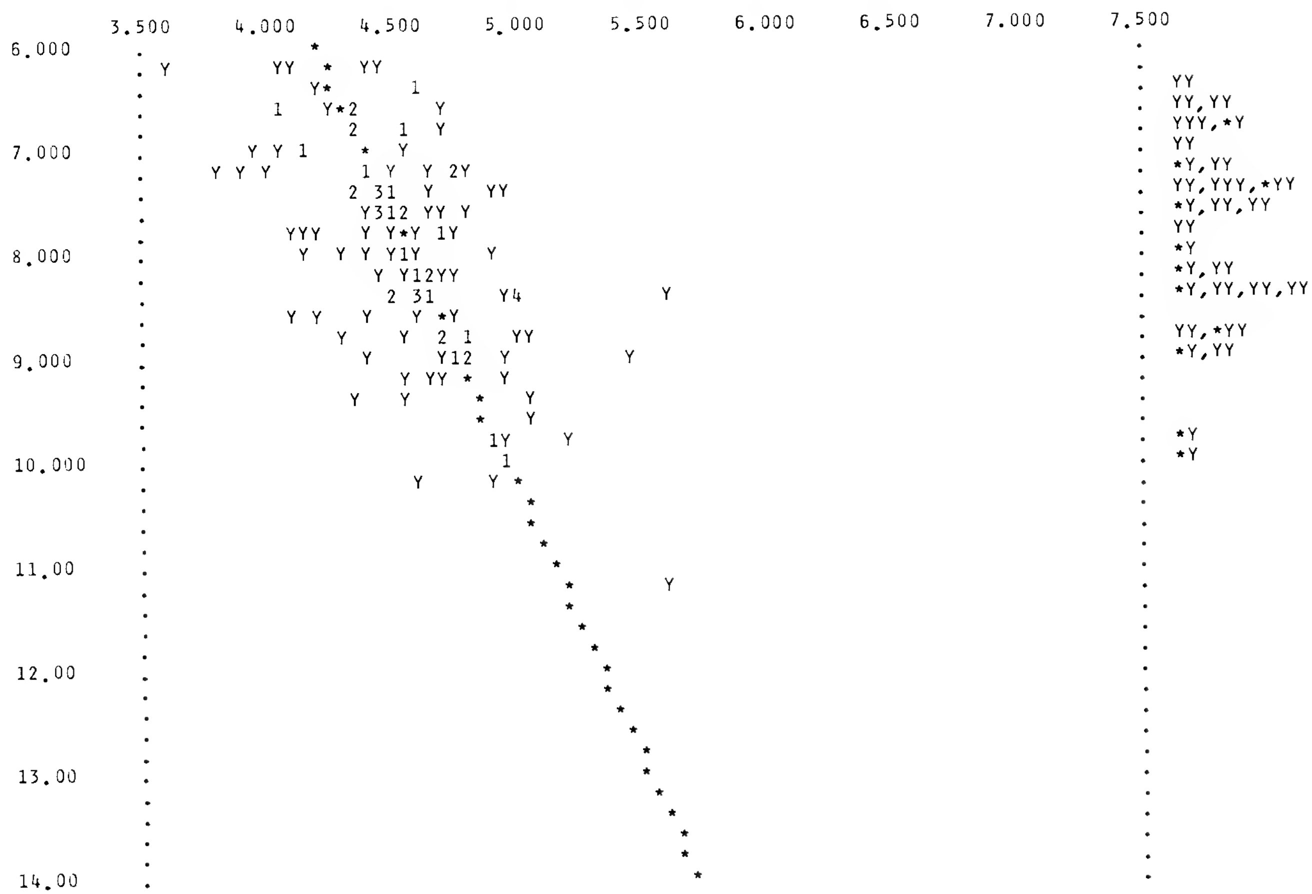

CHART III-1

LOG AVG. EXPENSES VS. LOG ESTABLISHMENT SIZE

HORIZONTAL - LOGEXP VERTICAL - ESTSIZ

1 TO 119 = Y

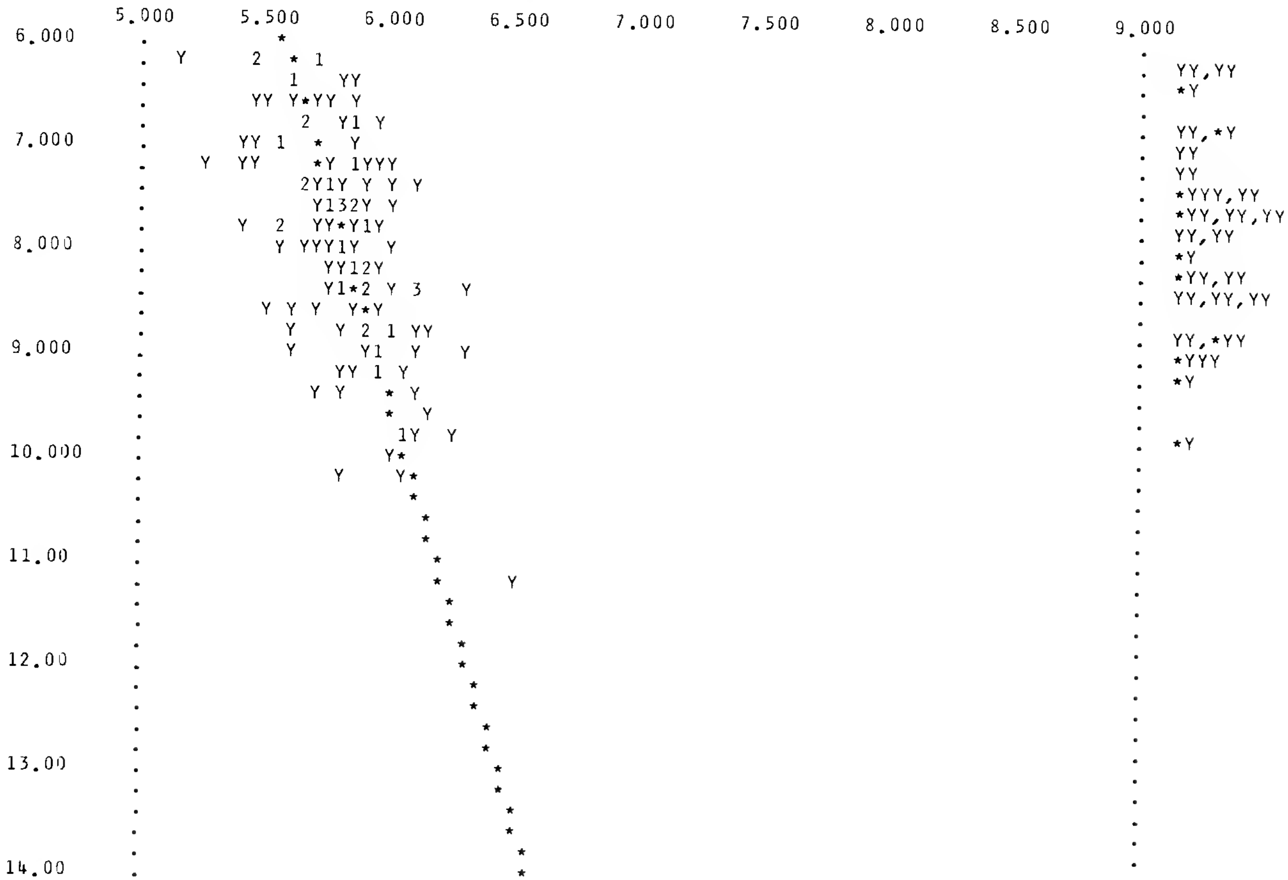

CHART III-2

LOG AVG. POWER VS. LOG ESTABLISHMENT SIZE

HORIZONTAL - LOGPOW   VERTICAL - ESTSIZ

1 TO 119 = Y

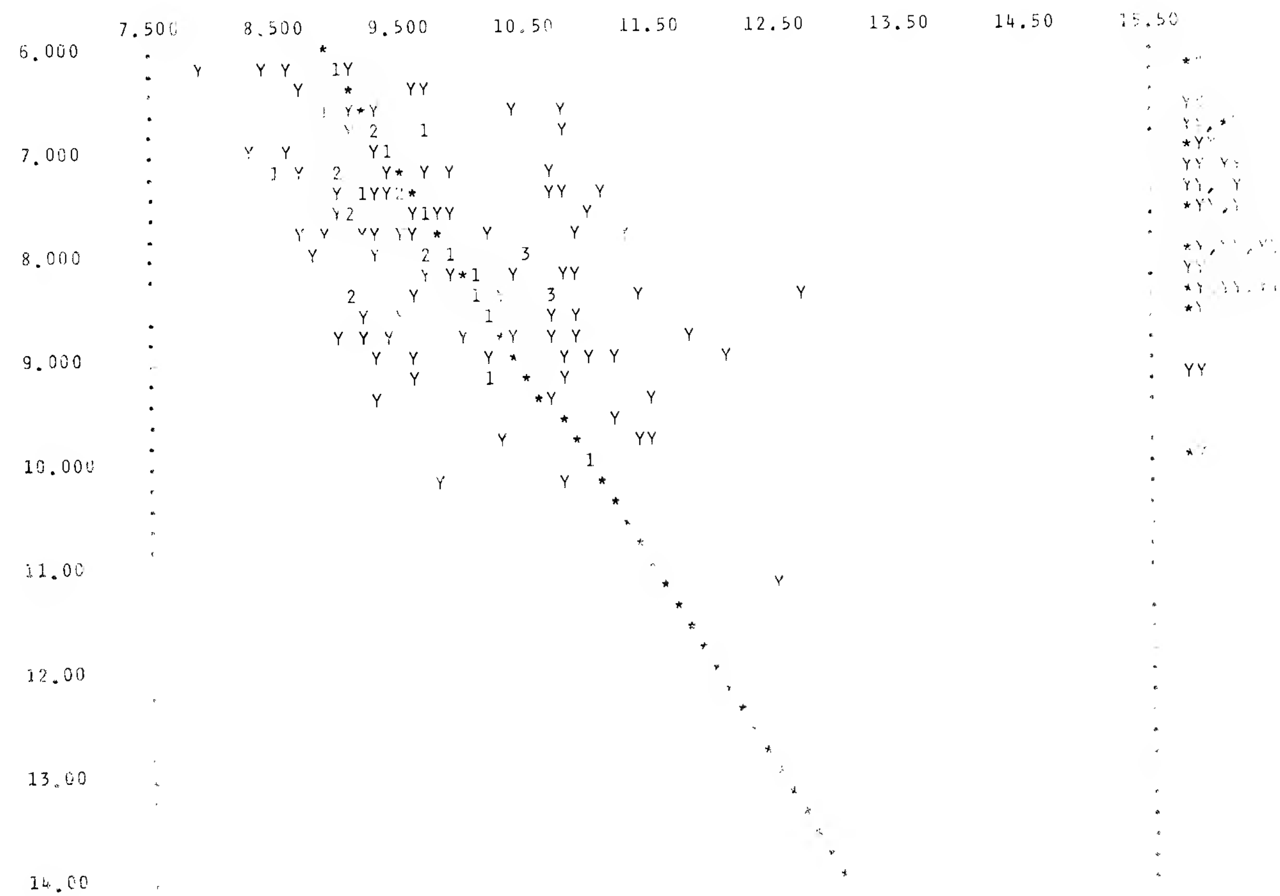

CHART III-3

CHAPTER FOUR

FINDINGS AND IMPLICATIONS FOR PUBLIC POLICY

The conclusion reached, as a result of the analyses carried out in this study, is that there is indeed certain evidence of the existence of economies of scale in the production of computing services. Given that this is the case, public policy ought to be formulated in a manner so as to encourage the more widespread use of larger size computing plants. The purpose of this concluding chapter is to review some of the the possible directions that public policy might take, and consider, for each, the relative appropriateness insofar as meeting the objective.

REGULATION AS A PUBLIC UTILITY

One of the most widely discussed directions for public policy is the establishment of a regulated computer utility, along fairly traditional lines. Indeed, the analysis presented here would seem to provide additional support for this view. However, the present study is inconclusive as to the rationality of this approach to policy formulation for several reasons.

In the traditional public utilities, such as electric power, the optimum size of plant is quite large; the capacity of an electric generator might be sufficient to

serve a city of one million people or more. To construct a plant of less than optimum size would be inefficient, so that the granting of an exclusive franchise to the power company in a particular area implies that public policy dictates that only plants of optimum size, or approaching optimum size, can be built. The same may be said for plants which generate computing power. However, we do not as yet know what is the optimum size of plant in this industry. Of perhaps even greater importance, we do not know the extent to which sharing and distribution costs will increase as machine size becomes sufficiently larger than the limits of present technology. The present analysis suggests that this optimum size is at least as large as the largest systems now built, but is inconclusive as to how much larger than the present scale the average cost curve becomes horizontal. There are a number of reasons for this lack of knowledge or experience with large systems, some of which have already been considered (Chapter two). But, for whatever the reasons, relatively few very large systems have actually been installed, at least by comparison with the number of small and medium size facilities. Further, and as a result, manufacturers of complete systems have not as yet built any system that is more than an order of magnitude away from what is presently considered to be a "large" system.

Regulation of the computer service industry as a public utility is indicated if it can be shown that computers can

operate far more efficiently if operated as very large scale systems, whose capacity far exceeds any one individual user's requirements. Hence, before any attempt is made to devise a structure for a regulated computer utility, some additional experience with large systems must be gathered. Thus, the most immediate objective of public policy should be to reduce or perhaps eliminate some of the presently existing barriers that mitigate against the (perhaps shared) use of the largest computers available.

BARRIERS TO USE OF LARGE SYSTEMS

In Chapter two we considered several of the short-run diseconomies that tend to induce end-users to continue to operate their own relatively small systems in-house. Briefly, these included the (perhaps psychological) desire to have hands-on control over the computer, the stickiness caused by the high cost of conversion to some other machine, the relative incompatibilities of different models and, in some cases, different units of the same model, and finally the costs, some direct and some indirect, of sharing one computer with other users. There are several means by which government authority, if properly directed, might reduce some of these barriers.

<u>Desire for control of the firm's computer</u>. Much of the reasoning behind a firm's desire to operate its own in-house computer installation may be traced to psychological factors such as the prestige associated with the machine, the

security over the company's files and records maintained on the computer, and the feeling that, so long as the machine is on the premises, the firm's work will get done. The prestige factor will, of course, wear off in time, as computers become more and more common and hence impress fewer and fewer people. However, suitable legislation can significantly alter the businessman's views concerning the other two issues. Operators of shared-use computer centers must not only guarantee the privacy of their client's files, but must assume a large measure of liability for any leakages that may be attributed to their negligence. Also, laws or regulations may fix limits of liability for uncompleted jobs that more closely reflect the cost, to the end-user, of the delay. At present, there is usually no such liability for assignments which the computer service organization could not complete either when due or at all.

<u>Costs of system conversion</u>. It is difficult to imagine any way in which the costs associated with conversion from one computer system to another could be significantly reduced or eliminated unless we were to adopt a policy of freezing technological innovation. Indeed, virtually no computer has ever had to be replaced because it was "worn out" by usage; most conversions from system to another have been the result of the user's desire to obtain the fullest advantage of the most current technology. However, if technology cannot be frozen, then conversion expenses may

still be reduced by encouraging the development of the relatively new software industry which has the potential of significantly reducing applications programming costs by sharing these costs among many clients who require basically the same applications programming package. Thus, software must be viewed as a product and must enjoy the same protection that is available to other products. Its uniqueness must be fully protected by copyright or, where appropriate, patent. Purchasers of computer hardware must not be required to pay for manufacturer-supplied software for which they have no need. With respect to software, policy should be directed at making a distinction between "computing power" and "computing service." Clearly, the greatest economies are potentially possible in the former sector of the industry, since raw power is, in effect, a common denominator that can satisfy the requirements of many end-users. Service, in contrast, must often be tailored to individual needs. Hence, an end-user should be able to supply his own programs, or contract for their development (or lease) and then be able to run his applications on any of, perhaps, a number of competing services. Thus, the separation between hardware and software should apply to more than the computer manufacturers, but also to the firms engaged in providing computing facilities for hire.

Sharing of computing facilities. The power produced by an electric generator may be shared among many individual

users because a distribution system exists to transmit the power from the generator to the user's home or factory. Although the electrical distribution system is costly to construct and maintain, the potential savings that result from the shared use of the generator more than outweigh these costs. A viable computer utility must also have a distribution network to transmit information between user and machine. For batch processing service bureaus, this network might consist of a fleet of messenger cars, or perhaps the U. S. mail. For on-line remote access systems, where the greatest potential for shared use lies, the distribution network would consist of telecommunications facilities to carry the two-directional flow of information electronically. The existing communications plant of the nation's communications common carriers is or can be more than adequate to serve as the distribution system for the on-line computer services. However, there are presently certain factors in the relationships between computer users and communications suppliers that may prevent the fullest advantage of the apparent economies of scale of computing systems from being made available to the public. Several recent works (1-3) have suggested the nature of some of these problems, including some of the responses to the FCC Inquiry. These include such issues as the right to interconnect privately-owned communications systems and apparatus to the common carrier lines with a minimum

interface requirement, the ability of several customers to share communications services in much the same way as they would share the computer's services, and the possible offering of services tailored specifically to certain computer communications requirements. It is essential that any barriers to the use of shared computer systems that may be attributable to policies and tariffs of communications suppliers be eliminated, where possible, and that the cost of this method of distributing the power not be so prohibitive as to negate any economies of large-scale computer operation.

LIMITATIONS OF LARGE SIZE COMPUTER SYSTEMS

We have suggested here that apparently significant cost savings might be realized by the more widespread use of large computer systems, perhaps on a shared bases. Indeed, recent developments in the art and technology of time-sharing and data communications make the prospect of more widespread use of large systems, perhaps simultaneously by many users, much more probable. However, the advantages of large scale computer facilities can only be realized, by many users sharing this facility, if the various costs associated with sharing are less than the direct cost advantage of the use of the large system. Certainly, communications costs, required in order to distribute the computing service to the users, may be a significant factor. However, several other possible costs include software

development, system overhead, administration, sales, and perhaps others. Modification in existing policy with respect to communications services might serve to decrease the significance of this cost area, although it is still not absolutely clear that this will be sufficient. As for software development costs and system overhead, present experience would seem to indicate that operational limitations may have been reached in the development of large-scale operating systems, a factor which could seriously limit the potential for development of large computers specifically designed for shared use. (i.e., a large system may be quite efficient if used by one organization for a limited number of different applications. However, when shared among a number of "hostile" subscribers, the software development costs and system overhead required to protect the users and the system and to provide for effective user-system communication and interface may prove greater than the economies of scale.)

What we have learned in this present investigation is that efforts must be directed toward providing the computer-using public with the advantages of large systems. This means that technology should be focused upon the possible solutions to some of the more formidable problems posed by shared use of large systems. Where possible, public authorities should seek to remove certain cost barriers particularly in the distribution sector of the

information processing field. The industry has demonstrated its ability to survive and prosper under a multi-plant, competitive environment. The computer utility, if it comes at all, will be the result of advances in the art of building, operating, and administering large-scale computing systems.

REFERENCES

(1) Gold, M. M. and L. L. Selwyn, "Real-Time Computer Communications and the Public Interest," AFIPS Conference Proceedings Vol. 33, Part 2, (1968 Fall Joint Computer Conference; New York: Thompson Book Company, 1968), pp. 1473-1478.

(2) Davies, D. W. et al, "A Digital Communications Network for computing giving rapid Response at Remote Terminals," ACM Symposium on Operating System Principles, October 1967 (Unpublished).

(3) Mills, R. G., "Communications Implications of the Project MAC Multiple-access Computer System," IEEE Convention Record, 1965.

APPENDIX

SOURCES AND DESCRIPTIONS OF EMPIRICAL DATA

The several sources of empirical data used to test the hypotheses described in this study are discussed in this appendix. The data fall into three broad categories, as follows:

(1) Manufacturing industries census data

(2) Computer installation data

(3) Computer cost data

Each category will be considered in turn below.

MANUFACTURING INDUSTRIES CENSUS DATA

The data on industry structures was obtained from several publications of the United States Department of Commerce, Bureau of the Census. They were based partly upon the 1963 Census of Manufactures and upon the 1966 Annual Survey of Manufactures. Manufacturing industries were chosen for analysis in this study because (a) they represent approximately one-third of the computer service market, and ((b) they are characterized by the most consistent and apparently accurate statistical reporting of any industry group.

The source documents referred to were:

(1) 1963 Census of Manufactures - Chapter 1, General Summary, and Chapter 2, Size of Establishments.

(2) "Concentration Ratios in Manufacturing Industry 1963," report prepared by the Bureau of the Census for the Subcommittee of Antitrust and Monopoly of the Committee on the Judiciary, United States Senate, 90th Congress, first session.

(3) 1966 Annual Survey of Manufactures, U. S. Department of Commerce Bureau of the Census, "Value of Shipment Concentration Ratios by Industry."

Six statistics were selected for each of the 417 manufacturing industries. The basis of selection was the apparent relevance to the use of computer services within each of the industries. Where possible, the statistics were obtained from the 1966 Annual Survey; however, in certain instances the 1966 figures were either missing or were ascribed questionable validity by the Bureau of the Census.

The Census of Manufactures is conducted every five years by the Bureau of the Census. It is, theoretically, an exhaustive canvass of all firms in all manufacturing industries. Manufacturing industries are those with Standard Industrial Classification (SIC) codes between 1900 and 3999. Industries 1900 - 1999 were a recent addition to the Manufacturing group, and, as a result, the statistics on these industries were not reported as consistently as for the remaining manufacturers. Hence, only data on industries

in the 2000 - 3999 range were used. The Annual Survey of Manufactures, in contrast to the Census, is based upon a statistical sample of firms in each of the industries covered. As a result, it is conceivable that certain figures reported in the Survey are relatively inaccurate. When the Bureau considered the standard error of estimate for any one industry to be sufficiently great that the accuracy of the data was open to question, it so indicated in the report as published. The six statistics used were selected because they provided measures of size, growth, concentration, establishment size, labor intensiveness, and capital intensiveness. Each is discussed below:

Industry size. Value of Shipments as reported in the 1966 Annual Survey of Manufactures was used as the measure of industry size. Certainly it is not the only possible measure of size (value added may be another). However, this statistic was selected because it provided a measure of the overall quantity of business done by the industry, not just in the actual manufacturing process itself. To eliminate sporatic variations in the more marginal industries, only industries with value of shipments in excess of $1 billion in 1966 were used in the analysis.

Growth. A measure of growth was provided by a ratio of the 1966 to 1963 value of shipments for each industry.

Concentration. As a measure of industry concentration, the ratio of value of shipments in the four largest firms to

the industry value of shipments, using the 1966 figures, was used. Industry concentration provides a measure of the relative size of the largest, and hence most important, firms in an industry.

Establishment size. A measure of establishment size in the four largest firms was obtained from the 1963 Concentration Ratio report. This statistic gives the number of individual establishments in the four largest firms. Thus, a large industry with a high concentration ratio and few establishments in the four largest firms would tend to be characterized by relatively large plants and establishments; one with many establishments, and perhaps a smaller concentration ratio or a small value of shipments, would exhibit establishments whose typical size is substantially smaller than in the first case.

Labor intensiveness. A ratio of Salaries and Wages/Adjusted Value Added was obtained from the Concentration Ratio report and subsequently was updated with data from the 1966 Annual Survey. This provides a measure of the relative use of labor in the manufacturing process in the industry.

Capital intensiveness. A ratio of New Capital Expenditures/Value of Shipments was used to provide a measure of the importance of current acquisition of new capital assets in the industry.

A summary of the above data for the 119 manufacturing industries used in the analysis are shown in Table A-1.

COMPUTER INSTALLATION DATA

The source of data on computer installations in the manufacturing industries was the "Computer Installation Data File" maintained by the Internation Data Corporation of Newton, Massachusetts. Access to this source file was provided for purposes of the research reported here.

The Computer Installation Data File contains descriptive data on individual computer installations in the United States. Included in the file are data on the using firm and data on the nature of the computer installation(s) operated by that firm. Although this data base does not have 100% coverage, the file's coverage is about 70% to 85% overall, with the greatest coverage in the larger size installations. Hence, the use of this data base necessitates some bias toward bigger machines and bigger installations. However, the coverage is fairly constant over most systems in the $5,000 per month and up range, covering most medium and large size systems, with the greatest deficiency occurring in the small, desk-top systems used primarily for specialized analysis and control purposes. Records containing data on nearly 10,000 individual machines installed at firms in the manufacturing industries was studied and analyzed.

Several attributes of each installation record were selected for use in this study. These were:

(1) The primary SIC code for the user company.

(2) The manufacturer and model number of the computer(s) installed in that company.

(3) Principal application areas of the computer installation, where available.

(4) System configuration data -

a) number of tapes

b) number of external memory devices

c) size of core memory

d) number of line printers

(5) Company sales and employee data

Although the Computer Installation Data File contains records of systems in all industry classifications, only the manufacturing industries, 2000 - 3999, were used in this study.

Each computer system (manufacturer model) type was classified according to several possible attributes: rent, power, and size class. Table A-2 presents a summary of these data for the machines considered. In certain cases, it was not possible to classify a given machine for one reason or another, due to lack of information on the nature of the system. However, in terms of market coverage, some 95% or more of all installed systems were classifiable.

Rent. The typical rent for a computer system type was obtained from several sources. A study was made of the rental ranges for computer systems installed in the Federal Government, where a fairly complete and consistently reported file of data on these costs exists (see below). In addition, several reference sources were consulted, including the Adams Associates "Computer Characteristics Quarterly" and the Auerbach Corporation's "Standard EDP Reports." Although some data on specific configurations was available from the Computer Installation Data File, it was determined that the use of typical system rentals was sufficiently accurate, and somewhat less biased, than the use of any basis for directly pricing out each installation. This is due to a general lack of overall consistency in the reporting in the CIDF, and the even greater difficulty of actually determining which specific components, having, in many instances, a wide range of costs, were in use at a particular installation. It is recognized that, as a result, the use of some "typical" installation rent may not directly provide a means of assessing the size of an installation at a given firm; however, with the rather large size of the sample used, nearly 10,000 individual systems, any discontinuities would be averaged out over all systems.

Power. A measure of the "power" of a specific computer system that was used is the result of a study by Kenneth E. Knight (9,10), that sought to assign a single dimension of

the quantity of processing per unit time to computer system types. This is, of course, a difficult task, since the "power" of any computer system is a function of the nature of the application to which it is applied and of the quality of the programs run. The same system may provide different quantities of service per unit time under different applications requirements, and the relative power of one system type to another system type may be quite different for different applications. This is because a computer system consists of several important components, each of which may have several performance attributes. Generally, business type applications require more input-output than do analysis type applications, which generally require more computation relative to I/O. Hence, a system with good input output capabilities relative to computation capabilities would tend to perform better under a business use than for scientific and technical applications. Besides the issue of input output versus computation, any system may have other sets of attributes that may render it better suited for one type of application over another. Knight recognized this and attempted to resolve it to some extent by determining, for each system he studied, power indices for both business and scientific use. This, of course, only reduces the extent of differences among the applications in each of these two categories, but does not eliminate the difficulty. For the purposes of the present study, the two

Knight indicies were weighted so as to form a single index. 75% of the greater of the two (business or scientific) was added to 25% of the lesser of the two Knight numbers. This was based upon the assumption that, in general, a machine would be used to process the most efficient type of application as its primary purpose. Although the index is imperfect, it does provide a means for examining the quantity of data processing provided by each system type. Whereas its usefulness for making comparisons between any given pair of machines is highly limited, its usefulness for the purpose of this study, where such comparisons are not important in relation to data on the orders of magnitude of processing power that is given by the indicies, the Knight figures seem quite appropriate and useful.

Size classification. Based upon a composite of rent, power, and other data available on each computer system, a classification into eight size classes was made. Table A-3 presents a summary of the characteristics of machines in each class.

A summary of computer characteristics for each of the 119 industries studied is presented in Table A-4. Table A-6 contains a summary of the relative importance of each of the three principal application areas within each industry.

INSTALLATION COST DATA

Public law 89-306, the so-called Brooks Act, established, within the Federal Government, an

administrative procedure for maintaining a consistent reporting mechanism for all computer installations in use by Federal government agencies and departments. While the primary purpose of this procedure was to facilitate greater sharing and economizing on the part of Federal agencies in their use of automatic data processing equipment, one of the by-products of this procedure was a consistently reported set of data on the nature of each installation in the government employ.

The Automatic Data Processing Management Information System program was established by order of the Bureau of the Budget. The system's purposes are :

> (a) provide to the Bureau of the Budget, the Department of Commerce, and the General Services Administration timely and comprehensive information to assist these agencies in the discharge of their responsibilities under Public Law 89-306.
> (b) provide assistance to agency heads in the administration and management of their automatic data processing activities,
> (c) provide a comprehensive and perpetual inventory of electronic data processing equipment, and
> (d) provide integrated subsystems for inventory, utilization, manpower, cost and acquisition history. . . . . (Ref. 6, p. 1)

The ADP Management Information Systems Office of the General Services Administration is charged with the responsibility for collecting and maintaining the data in the ADP file. The use of this data was made possible by that Office.

U.S. government use of computers represents about 12% of the computer market in this country. Generaly, the systems are obtained from the manufacturer, either on a lease or through outright purchase, at full list price.

Further, the nature of a computer installation in a government agency is quite similar to one that might be found in any civilian organization. Hence, it appears to be quite reasonable to draw some general conclusions as to the nature of all installations from this admittedly biased sample of such facilities that is limited to Federal government operation.

<u>Computer System Cost Data</u>. An individual record for each installation contains a complete breakdown of all components in the one or more computer systems present at the particular site. As a result, it was possible to obtain a cost distribution of the various configurations of each type of system installed in the Federal Government. Generally, the average rent of all instances of the same system model type was used as a basis for classifying computer system types into the eight size classes (see above) and for assigning typical configuration rentals to that system type. Where the federal government data seemed to be inconsistent with the cost figures published in one of the aforementioned reference sources, further study was necessary in order to determine the correct rental figure to be assigned to a system. The rental figures for Federal Government computer installations, as obtained from the Automatic Data Processing Management Information System data file are presented in Table A-5. Rental values are used because they seem to be the most consistently reported

figure. This is true even if the computer system was purchased by the Federal agency. The actual rental price, or its equivalent if the system were purchased, is required in the report of each agency's installations to the General Services Administration for purposes of the ADP file.

Operating Costs. In addition to hardware cost data, the ADP Management Information System file contains a breakdown of operating costs of installations other than the actual hardware rental (or equivalent) of the computer(s) present. Several cost categories are provided for reporting expenses:

(1) Civilian Salaries and overtime (exclusive of employee fringe benefits)

(2) Military Base Pay and Allowances (where applicable)

(3) Punched Card Equipment rentals (includes all EAM equipment, such as key punches, sorters, etc. that support the computer system)

(4) Magnetic tapes and disk packs used

(5) Parts for in-house maintenance of purchased EDP equipment

(6) Supplies used (paper, cards, etc.)

(7) Other operating expenses not classified

These cost figures were used as the basis for the model of installation operating costs vs. computer rental costs discussed earlier.

REFERENCES

Manufacturing Industry Data:

(1) U. S. Bureau of the Census, "Census of Manufactures, 1963," Chapter 1, General Summary; Chapter 2, Size of Establishments

(2) U. S. Bureau of the Census, "Concentration Ratios in Manufacturing Industry 1963, Part II," report prepared for the Subcommittee on Antitrust and Monopoly of the Committee on the Judiciary, United States Senate.

(3) U. S. Bureau of the Census, "Annual Survey of Manufactures, 1966," General Statistics section and Value of Shipments Concentration Ratios by Industry.

Computer Installation Data

(4) International Data Corporation, Newton, Mass., "Program Description: The International Data Corporation's Computer Installation Data File," (unpublished).

(5) International Data Corporation, "Sponsor's Coding Interpretation Manual for the Computer Installation Data File," (unpublished).

System and Installation Cost Data

(6) Executive Office of the President, U. S. Bureau of the Budget, Circular A-83, "ADP Management Information System," April 20, 1967.

(7) Adams Associates, Inc., <u>Computer Characteristics Quarterly</u>, Fourth Quarter, 1968.

(8) Auerbach Corporation, <u>Standard EDP Reports</u>.

(9) Knight, Kenneth E. (1966), <u>op. cit.</u>

(10) Knight, Kenneth E. (1968), <u>op. cit.</u>

TABLE A-1: INDUSTRY CHARACTERISTICS

SIC	INDUSTRY NAME	(1) SIZE	(2) GROWTH	(3) CONC	(4) ESTAB	(5) CAP	(6) LABOR
2011	MEAT SLAUGHTERING PLANTS	15069	121	27	91	1	60
2013	MEAT PROCESSING PLANTS	2502	117	16	29	1	51
2023	CONDENSED AND EVAPORATED MILK	1100	117	45	80	1	24
2024	ICE CREAM AND FROZEN DESSERTS	1142	106	33	84	2	38
2026	FLUID MILK	7435	105	23	259	1	47
2032	CANNED SPECIALTIES	1457	121	63	14	3	24
2033	CANNED FRUITS AND VEGETABLES	3216	117	24	62	3	34
2037	FROZEN FRUITS AND VEGETABLES	1885	121	26	27	4	39
2041	FLOUR MILLS	2345	107	31	56	2	31
2042	PREPARED ANIMAL FEEDS	4438	114	23	85	1	29
2051	BREAD AND RELATED PRODUCTS	5007	111	25	232	3	53
2052	BISCUITS, CRACKERS, AND COOKIES	1327	115	59	31	2	33
2071	CONFECTIONARY PRODUCTS	1681	115	24	6	3	41
2082	MALT LIQUOR	3700	116	38	23	6	36
2085	DISTILLED LIQUOR, EXCEPT BRANDY	1332	122	55	28	2	18
2086	BOTTLED AND CANNED SOFT DRINKS	2735	123	18	77	6	45
2099	FOOD PREPARATIONS, N.E.C.	2206	122	26	64	4	31
2111	CIGARETTES	2860	107	81	9	1	14
2211	WEAVING MILLS, COTTON	2562	114	30	57	6	21
2221	WEAVING MILLS, SYNTHETIC	2241	130	40	48	6	56
2231	WEAVING, FINISHING MILLS, WOOL	1167	115	58	32	3	50
2253	KNIT OUTERWEAR MILLS	1273	121	14	4	4	58
2281	YARN MILLS, EXCEPT WOOL	1479	138	19	28	7	52
2311	MEN'S AND BOYS' SUITS AND COATS	1850	121	17	19	1	59
2321	MEN'S DRESS SHIRTS AND NIGHTWEAR	1348	104	25	41	1	60
2327	SEPARATE TROUSERS	1042	126	20	16	1	61
2328	WORK CLOTHING	1052	127	28	42	2	54
2335	DRESSES	2508	104	8	40	1	58
2341	WOMEN'S AND CHILDREN'S UNDERWEAR	1042	106	15	22	1	69
2421	SAWMILLS AND PLANING MILLS	3391	107	11	54	5	56

TABLE A-1 (CONTINUED)

SIC	INDUSTRY NAME	(1) SIZE	(2) GROWTH	(3) CONC	(4) ESTAB	(5) CAP	(6) LABOR
2431	MILLWORK PLANTS	1345	105	9	9	2	63
2432	VENEER AND PLYWOOD PLANTS	1700	126	24	51	4	62
2511	WOOD FURNITURE, NOT UPHOLSTERED	2423	130	12	19	3	57
2512	WOOD FURNITURE, UPHOLSTERED	1250	127	15	22	2	57
2621	PAPER MILLS, EXCEPT BUILDING	4805	125	24	45	12	45
2631	PAPERBOARD MILLS	2853	123	27	33	9	34
2641	PAPER COATING AND GLAZING	1383	119	28	28	4	41
2643	BAGS, EXCEPT TEXTILE BAGS	1358	127	23	38	4	49
2653	CORRUGATED SHIPPING CONTAINERS	2891	133	18	100	4	58
2711	NEWSPAPERS	5520	123	14	29	4	53
2721	PERIODICALS	2718	118	28	5	1	32
2731	BOOKS, PUBLISHING AND PRINTING	1996	130	20	6	2	27
2751	PRINTING, EXCEPT LITHOGRAPHIC	3202	121	14	15	4	63
2752	PRINTING, LITHOGRAPHIC	2701	129	5	13	4	62
2815	INTERMEDIATE COAL TAR PRODUCTS	[illegible]	133	52	15	6	32
2818	ORGANIC CHEMICALS, N.E.C.	6541	135	46	28	14	23
2819	INORGANIC CHEMICALS, N.E.C.	3905	110	29	75	9	29
2821	PLASTICS MATERIALS AND RESINS	3532	137	32	21	8	33
2824	ORGANIC FIBERS, NONCELLULOSIC	1902	141	85	14	19	32
2834	PHARMACEUTICAL PREPARATIONS	[illegible]	133	24	13	3	22
2841	SOAP AND OTHER DETERGENTS	2396	112	72	25	1	17
2842	POLISHES AND SANITATION GOODS	1029	136	30	14	3	23
2844	TOILET PREPARATIONS	2431	135	40	14	1	15
2851	PAINTS AND ALLIED PRODUCTS	2970	120	23	38	2	36
2871	FERTILIZERS	1183	136	34	12	7	30
2899	CHEMICAL PREPARATIONS, N.E.C.	1322	141	20	15	3	31
2911	PETROLIUM REFINING	18742	113	32	45	3	22
3011	TIRES AND INNER TUBES	3716	125	71	32	4	44
3069	RUBBER PRODUCTS, N.E.C.	3139	120	22	21	3	53
3079	PLASTICS PRODUCTS, N.E.C.	4658	147	8	39	7	49

TABLE A-1 (CONTINUED)

SIC	INDUSTRY NAME	(1) SIZE	(2) GROWTH	(3) CONC	(4) FSTAR	(5) CAP	(6) LABOR
3141	SHOES, EXCEPT RUBBER	2650	117	26	108	1	57
3221	GLASS CONTAINERS	1207	120	59	40	10	51
3241	CEMENT, HYDRAULIC	1253	106	30	56	8	29
3291	ABRASIVE PRODUCTS	1016	144	56	14	4	40
3312	BLAST FURNACES AND STEEL MILLS	21193	127	49	57	8	47
3317	STEEL PIPE AND TUBE	1072	132	26	10	3	47
3321	GRAY IRON FOUNDRIES	2728	137	27	23	8	59
3323	STEEL FOUNDRIES	1279	146	22	14	4	1580
3351	COPPER ROLLING AND DRAWING	2446	171	43	24	2	35
3352	ALUMINUM ROLLING AND DRAWING	3100	141	65	33	4	57
3356	ROLLING AND DRAWING, N.E.C.	1051	163	46	11	5	44
3357	NONFERROUS WIRE DRAWING, ETC.	3711	175	39	41	2	36
3391	IRON AND STEEL FORGINGS	1273	146	31	7	3	58
3411	METAL CANS	2631	126	71	113	4	43
3429	HARDWARE, N.E.C.	2344	131	38	14	4	48
3433	HEATING EQUIPMENT, EXCEPT ELECTRIC	1167	114	16	11	2	49
3441	FABRICATED STRUCTURAL STEEL	2602	135	14	32	1	63
3442	METAL DOORS, SASH, AND TRIM	1597	111	10	11	2	56
3443	BOILER SHOP PRODUCTS	2323	143	28	27	3	54
3452	BOLTS, NUTS, RIVETS AND WASHERS	1662	136	18	23	4	48
3461	METAL STAMPINGS	3756	140	11	19	4	56
3481	FABRICATED METAL PRODUCTS, N.E.C.	1300	126	13	21	3	54
3494	VALVES AND PIPE FITTINGS	2209	139	13	20	3	49
3519	INTERNAL COMBUSTION ENGINES	2052	139	52	13	4	46
3522	FARM MACHINERY AND EQUIPMENT	4332	152	45	25	3	47
3531	CONSTRUCTION MACHINERY	3768	139	45	17	3	48
3541	METAL-CUTTING MACHINE TOOLS	1826	172	22	10	4	55
3544	SPECIAL DIES AND TOOLS	2218	159	5	10	6	62
3545	MACHINE TOOLS AND ACCESSORIES	1230	156	20	13	4	49
3548	METALWORKING MACHINERY, N.E.C.	1148	144	25	11	4	49

TABLE A-1 (CONTINUED)

SIC	INDUSTRY NAME	(1) SIZE	(2) GROWTH	(3) CONC	(4) ESTAB	(5) CAP	(6) LABOR
3559	SPECIAL INDUSTRY MACHINERY, N.E.C.	1731	170	10	5	4	55
3561	PUMPS AND COMPRESSORS	2161	151	27	15	3	48
3562	BALL AND ROLLER BEARINGS	1399	140	56	23	7	53
3566	POWER TRANSMISSION EQUIPMENT	1314	147	25	10	4	50
3569	GENERAL INDUSTRY MACHINES, N.E.C.	1024	148	21	5	3	48
3585	REFRIGERATION MACHINERY	2713	140	34	10	3	46
3599	MISC. MACHINERY	2865	140	6	10	5	57
3611	ELECTRIC MEASURING INSTRUMENTS	1020	136	36	13	3	52
3612	TRANSFORMERS	1053	145	66	18	4	48
3613	SWITCHGEAR AND SWITCHBOARDS	1549	141	52	41	2	46
3621	MOTORS AND GENERATORS	2289	133	48	35	4	53
3622	INDUSTRIAL CONTROLS	1049	161	50	12	3	45
3634	ELECTRIC HOUSEWARES AND FANS	1128	132	50	14	2	38
3642	LIGHTING FIXTURES	1544	133	18	12	3	48
3651	RADIO AND TV RECEIVING SETS	4092	181	48	11	3	41
3661	TELEPHONE, TELEGRAPH APPARATUS	2457	142	94	24	4	54
3662	RADIO, TV COMMUNICATIONS EQUIPMENT	7563	105	24	28	2	64
3674	SEMICONDUCTORS	1124	163	51	5	11	59
3679	ELECTRONIC COMPONENTS, N.E.C.	4002	171	22	19	4	51
3694	ENGINE ELECTRICAL EQUIPMENT	1342	148	72	11	3	49
3717	MOTOR VEHICLES AND PARTS	45630	126	79	135	2	42
3721	AIRCRAFT	9000	142	67	9	4	69
3722	AIRCRAFT ENGINES AND PARTS	4572	111	58	15	4	61
3729	AIRCRAFT EQUIPMENT, N.E.C.	3781	119	26	11	3	63
3731	SHIP BUILDING AND REPAIRING	2339	139	42	19	2	78
3742	RAILROAD AND STREET CARS	1696	182	50	11	2	50
3821	MECHANICAL MEASURING DEVICES	1429	125	21	14	3	53
3861	PHOTOGRAPHIC EQUIPMENT	3286	177	67	10	5	31
3941	GAMES AND TOYS	1157	145	22	10	2	45

TABLE A-1 (CONTINUED)

EXPLANATION OF COLUMNS

(1) 1966 Value of Shipments

(2) 1966 Value of Shipments / 1963 Value of Shipments

(3) Value of Shipments of four largest firms / Industry Value of Shipments (1966 figures)

(4) Number of individual establishments in the four largest firms (1963 figures)

(5) New capital investment / Value of Shipments (1966 figures)

(6) Wages and Salaries / Adjusted Value Added (1966 figures)

Dollar figures in $ millions

TABLE A-2
COMPUTER SIZE AND POWER DATA

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
ASI	210	2	7679.50	8868.00	4114.00
ASI	2100	3	21031.25	24628.00	10241.00
ASI	6020	3	24410.25	28160.00	13161.00
ASI	6040	3	N.A.	N.A.	N.A.
ASI	6050	3	N.A.	N.A.	N.A.
ASI	6130	3	N.A.	N.A.	N.A.
AUT	REC2	1	38.05	41.36	28.03
AUT	REC3	1	45.15	48.28	35.76
BRA	230	0	N.A.	N.A.	N.A.
BRA	300	0	N.A.	N.A.	N.A.
BRA	330	0	N.A.	N.A.	N.A.
BRA	340	3	N.A.	N.A.	N.A.
BUR	220	5	1416.55	810.20	1616.00
BUR	E101	1	1.78	.68	2.15
BUR	E103	1	1.78	.68	2.15
BUR	E2100	0	N.A.	N.A.	N.A.
BUR	B100	2	N.A.	N.A.	N.A.
BUR	B250	2	N.A.	N.A.	N.A.
BUR	B263	2	N.A.	N.A.	N.A.
BUR	B270	2	N.A.	N.A.	N.A.
BUR	B280	2	N.A.	N.A.	N.A.
BUR	B200	2	N.A.	N.A.	N.A.
BUR	B5500	5	502219.50	376275.00	544201.00
BUR	B300	3	N.A.	N.A.	N.A.
BUR	B8500	0	N.A.	N.A.	N.A.
BUR	B2500	3	27131.50	22153.00	28791.00
BUR	B3500	4	148694.25	154842.00	130251.00
BUR	B6500	5	3034389.48	3127266.00	2755760.00
BUR	B500	2	N.A.	N.A.	N.A.
HON	DDP24	3	619.67	580.40	632.76
HON	DDP224	3	74201.50	52330.00	81492.00
HON	DDP116	2	3561.00	2175.00	4023.00
HON	DDP124	2	7166.50	5812.00	7618.00
HON	DDP516	1	N.A.	N.A.	N.A.
CDC	G15D	1	50.57	57.34	50.25
CDC	G20	4	62610.00	37260.00	71060.00
CDC	160	3	101.88	119.30	49.63
CDC	160A	3	1588.75	1015.00	1780.00
CDC	160B	4	N.A.	N.A.	N.A.
CDC	924	4	N.A.	N.A.	N.A.
CDC	924A	4	N.A.	N.A.	N.A.
CDC	1604	5	48815.00	58290.00	20390.00
CDC	1604A	6	N.A.	N.A.	N.A.
CDC	3600	6	383392.50	459065.00	156375.00
CDC	3400	5	241694.75	269859.00	157202.00

TABLE A-2 (CONTINUED)

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
CDC	3200	4	168319.50	195256.00	87510.00
CDC	6600	8	6289037.46	7021618.96	4091293.00
CDC	1604B	8	N.A.	N.A.	N.A.
CDC	3100	4	107444.25	118462.00	74391.00
CDC	3300	5	N.A.	N.A.	N.A.
CDC	3800	6	555564.00	690510.00	150726.00
CDC	3150	4	N.A.	N.A.	N.A.
CDC	636	0	N.A.	N.A.	N.A.
CDC	6400	6	570510.75	696086.00	193785.00
CDC	8090	2	N.A.	N.A.	N.A.
CDC	1700	3	N.A.	N.A.	N.A.
DEQ	PDP1	2	3884.50	4455.00	2173.00
DEQ	PDP4	2	186.14	220.20	75.97
DEQ	PDP5	1	10973.75	6338.00	12519.00
DEQ	PDP6	3	42970.00	46359.00	32803.00
DEQ	PDP7	2	58765.50	68497.00	29571.00
DEQ	PDP8	1	1573.75	1768.00	991.00
DEQ	LINC8	1	N.A.	N.A.	N.A.
DEQ	PDP8S	1	6808.25	1595.00	8546.00
DEQ	PDP10	4	N.A.	N.A.	N.A.
DEQ	PDP8I	1	6808.25	1595.00	8546.00
FRI	6010	1	36.91	1.66	48.66
GEL	205	2	5088.75	1775.00	6188.00
GEL	215	3	6504.50	5246.00	6924.00
GEL	225	3	6989.75	6566.00	7131.00
GEL	235	5	26978.75	28557.00	22244.00
GEL	415	4	13634.00	7472.00	15688.00
GEL	425	4	19491.25	11485.00	22160.00
GEL	435	5	48668.00	24803.00	56623.00
GEL	304	0	N.A.	N.A.	N.A.
GEL	625	6	197819.00	224374.00	118154.00
GEL	635	7	317693.00	338958.00	253898.00
GEL	4020	3	N.A.	N.A.	N.A.
GEL	405011	3	N.A.	N.A.	N.A.
GEL	420	4	N.A.	N.A.	N.A.
GEL	4040	2	N.A.	N.A.	N.A.
GEL	312	2	103.28	122.00	47.12
GEL	412	3	N.A.	N.A.	N.A.
GEL	115	2	N.A.	N.A.	N.A.
GEL	D30	3	N.A.	N.A.	N.A.
GEL	4060	3	N.A.	N.A.	N.A.
GEL	4000	0	N.A.	N.A.	N.A.
GEL	406	0	N.A.	N.A.	N.A.
GEL	4120	0	N.A.	N.A.	N.A.
GEL	265	0	N.A.	N.A.	N.A.

TABLE A-2 (CONTINUED)

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
GE	405	0	N.A.	N.A.	N.A.
GNP	LGP21	0	N.A.	N.A.	N.A.
GNP	LGP30	3	N.A.	N.A.	N.A.
GNP	4000	2	N.A.	N.A.	N.A.
HON	200	3	5557.25	1148.00	7027.00
HON	400	4	2402.50	1354.00	2752.00
HON	800	5	27532.50	28790.00	23760.00
HON	H1400	4	5558.25	1770.00	6821.00
HON	1800	6	97387.50	110600.00	57750.00
HON	290	3	311.42	354.30	182.80
HON	610	3	N.A.	N.A.	N.A.
HON	2200	4	13804.50	12222.00	14332.00
HON	H20	0	N.A.	N.A.	N.A.
HON	H21	0	N.A.	N.A.	N.A.
HON	120	2	7668.50	2100.00	9526.00
HON	1200	4	8712.75	2130.00	10907.00
HON	H4200	5	42244.25	45569.00	32270.00
HON	H8200	6	N.A.	N.A.	N.A.
HON	H125	3	N.A.	N.A.	N.A.
HON	H110	2	N.A.	N.A.	N.A.
HON	H1250	4	N.A.	N.A.	N.A.
IBM	305	2	95.97	94.47	96.67
IBM	36030	4	14813.50	7942.00	17104.00
IBM	36040	5	45814.25	33438.00	50073.00
IBM	36050	5	177857.75	187488.00	148967.00
IBM	650	2	246.02	110.80	291.10
IBM	1401	3	811.07	340.90	967.80
IBM	1401G	2	811.07	340.90	967.80
IBM	1410	5	3896.75	1673.00	4638.00
IBM	1440	3	4522.25	1412.00	5559.00
IBM	1460	4	5802.75	1611.00	7200.00
IBM	1620	2	82.89	94.70	47.20
IBM	7010	6	10885.00	5729.00	11537.00
IBM	704	5	8948.75	10670.00	3785.00
IBM	7040	5	18334.75	21420.00	9079.00
IBM	7044	6	56600.00	67660.00	23420.00
IBM	705	5	1748.75	734.00	2087.00
IBM	7070	5	4557.50	2813.00	5139.00
IBM	7074	6	39405.00	41990.00	31650.00
IBM	7080	7	28817.50	27090.00	30860.00
IBM	709	6	16578.00	18690.00	10230.00
IBM	7090	7	86380.00	97350.00	65470.00
IBM	7094	7	155800.00	175900.00	95900.00
IBM	7094II	7	186617.50	217108.00	95146.00
IBM	1710	6	N.A.	N.A.	N.A.

TABLE A-2 (CONTINUED)

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
IBM	7740	4	N.A.	N.A.	N.A.
IBM	1401H	2	811.07	340.90	967.80
IBM	610	1	N.A.	N.A.	N.A.
IBM	6400	1	N.A.	N.A.	N.A.
IBM	1620I	2	82.89	94.79	47.20
IBM	1620II	3	N.A.	N.A.	N.A.
IBM	36020	2	3855.75	1932.00	4497.00
IBM	1800	3	N.A.	N.A.	N.A.
IBM	1130	1	46.66	16.38	58.76
IBM	36065	6	1241614.25	1385573.00	809738.00
IBM	36067	7	1241614.25	1385573.00	809738.00
IBM	36075	8	3030092.00	3560854.00	1437806.00
IBM	36090	8	N.A.	N.A.	N.A.
IBM	1974	0	N.A.	N.A.	N.A.
IBM	36044	4	984085.75	1025941.00	858520.00
IBM	36091	8	N.A.	N.A.	N.A.
IBM	36025	3	N.A.	N.A.	N.A.
IBM	36085	8	N.A.	N.A.	N.A.
IBM	360/*	3	N.A.	N.A.	N.A.
MON	MON-IX	1	1.12	.46	1.33
MON	MON-XI	1	8.93	4.84	10.30
NCR	304	4	2117.75	1136.00	2445.00
NCR	310	2	101.88	119.30	49.63
NCR	315	4	9447.00	3408.00	11460.00
NCR	390	1	8.33	2.03	10.43
NCR	441-22	0	N.A.	N.A.	N.A.
NCR	590	1	17.39	4.29	21.76
NCR	395	1	N.A.	N.A.	N.A.
NCR	500	1	N.A.	N.A.	N.A.
NCR	315RMC	4	8263.00	3364.00	9896.00
NCR	CEN100	2	N.A.	N.A.	N.A.
NCR	CEN200	3	N.A.	N.A.	N.A.
NCR	CEN*	2	N.A.	N.A.	N.A.
RAY	250	1	52.22	62.23	22.21
RAY	440	3	N.A.	N.A.	N.A.
RAY	520	3	25195.25	29118.00	13427.00
PHI	1000	4	9532.75	6811.00	10440.00
PHI	2M-212	6	298407.50	369800.00	84230.00
PHI	2000	6	N.A.	N.A.	N.A.
PHI	2M-211	6	93318.00	105844.00	55740.00
PHI	3100	0	N.A.	N.A.	N.A.
RCA	301	4	872.00	323.00	1055.00
RCA	3301	5	109860.50	126761.00	58359.00
RCA	501	4	1567.42	638.70	1877.00
RCA	601	5	66237.50	68690.00	58880.00

TABLE A-2 (CONTINUED)

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
RCA	7015	2	12898.75	1837.00	16586.00
RCA	7025	3	28479.00	4818.00	36366.00
RCA	7045	4	270772.25	211610.00	290493.00
RCA	7055	5	1311851.50	1341132.00	1224010.00
RCA	7035	4	110089.75	61186.00	126391.00
RCA	7046	5	N.A.	N.A.	N.A.
RCA	110	0	N.A.	N.A.	N.A.
RCA	70/*	3	N.A.	N.A.	N.A.
SDS	910	2	4219.50	4841.00	2355.00
SDS	920	3	8174.00	9244.00	4964.00
SDS	930	3	60144.50	73181.00	21035.00
SDS	9300	4	35568.50	43876.00	10646.00
SDS	92	3	64083.75	19140.00	79065.00
SDS	925	3	135749.50	92692.00	150102.00
SDS	SIGMA7	4	809494.50	894566.00	554280.00
SDS	SIGMA2	2	113883.75	118152.00	101079.00
SDS	SIGMA5	3	N.A.	N.A.	N.A.
UNI	I	5	238.97	140.10	271.40
UNI	II	5	2061.00	1155.00	2363.00
UNI	SSII	5	N.A.	N.A.	N.A.
UNI	III	5	22772.50	22720.00	22790.00
UNI	FCII	5	79.23	33.46	94.49
UNI	SS80	4	N.A.	N.A.	N.A.
UNI	SS90	3	N.A.	N.A.	N.A.
UNI	418	4	139614.75	58767.00	166564.00
UNI	490	6	17090.00	17770.00	15050.00
UNI	1004	2	19.41	1.79	25.29
UNI	1050	3	17763.25	12028.00	19675.00
UNI	1050-3	3	N.A.	N.A.	N.A.
UNI	1105	6	5253.50	4433.00	5527.00
UNI	U60	1	N.A.	N.A.	N.A.
UNI	1218	2	N.A.	N.A.	N.A.
UNI	1107	6	123037.50	138700.00	76050.00
UNI	1005	2	907.43	71.73	1186.00
UNI	1040	0	N.A.	N.A.	N.A.
UNI	1108	7	N.A.	N.A.	N.A.
UNI	9200	1	5991.50	1592.00	7458.00
UNI	9300	2	14905.50	4350.00	18424.00
UNI	1206	6	N.A.	N.A.	N.A.
UNI	491	6	49090.00	49290.00	48490.00
UNI	492	6	N.A.	N.A.	N.A.
UNI	494	6	1468290.00	1291740.00	1527140.00
UNI	1230	3	N.A.	N.A.	N.A.
UNI	1219	4	N.A.	N.A.	N.A.
UNI	9400	3	N.A.	N.A.	N.A.

TABLE A-2 (CONTINUED)

MANU	MODEL	CLASS	COMB POWER	SCI POWER	BUS POWER
EAI	8400	4	N.A.	N.A.	N.A.
EAI	640	1	N.A.	N.A.	N.A.
EAI	8800	0	N.A.	N.A.	N.A.
PDS	1020	1	N.A.	N.A.	N.A.
SEL	810	3	N.A.	N.A.	N.A.
COL	8401A	0	N.A.	N.A.	N.A.
COL	8500A	0	N.A.	N.A.	N.A.
DSC	1000	0	N.A.	N.A.	N.A.
VAR	DMI620	0	N.A.	N.A.	N.A.
VAR	DM620I	0	N.A.	N.A.	N.A.
FOX	97400	0	N.A.	N.A.	N.A.
FOX	97600	0	N.A.	N.A.	N.A.
FOX	97600A	0	N.A.	N.A.	N.A.
SCC	670	2	N.A.	N.A.	N.A.
WES	PRO580	0	N.A.	N.A.	N.A.
WES	PRO50	0	N.A.	N.A.	N.A.
WES	PRO510	0	N.A.	N.A.	N.A.
SYL	9400	5	59270.00	62510.00	49550.00
ISI	609	0	N.A.	N.A.	N.A.

TABLE A-3

COMPUTER SIZE CLASS DEFINITIONS

CLASS	RENTAL RANGE		MEAN RENT
1	0	<2000	1381
2	2000	<5000	3270
3	5000	<10000	7386
4	10000	<20000	13201
5	20000	<40000	28751
6	40000	<70000	52213
7	70000	<100000	86287
8	100000	& over	227367

Rental figures are monthly

TABLE A-4: CHARACTERISTICS OF COMPUTERS BY INDUSTRY

SIC	INDUSTRY NAME	(1) NO.COMP.	(2) AVGRNT	(3) AVGEXP	(4) AVGPOW
2011	MEAT SLAUGHTERING PLANTS	106	88	325	9021
2013	MEAT PROCESSING PLANTS	27	55	237	4755
2023	CONDENSED AND EVAPORATED MILK	19	98	334	15088
2024	ICE CREAM AND FROZEN DESSERTS	33	81	304	8272
2026	FLUID MILK	39	67	264	5770
2032	CANNED SPECIALTIES	19	120	400	45608
2033	CANNED FRUITS AND VEGETABLES	65	103	353	12517
2037	FROZEN FRUITS AND VEGETABLES	31	88	319	10359
2041	FLOUR MILLS	34	114	357	43336
2042	PREPARED ANIMAL FEEDS	41	65	254	11068
2051	BREAD AND RELATED PRODUCTS	45	59	236	5368
2052	BISCUITS, CRACKERS, AND COOKIES	16	109	362	84868
2071	CONFECTIONARY PRODUCTS	33	74	276	7954
2082	MALT LIQUOR	40	105	361	45959
2085	DISTILLED LIQUOR, EXCEPT BRANDY	29	117	385	13634
2086	BOTTLED AND CANNED SOFT DRINKS	27	57	169	2661
2099	FOOD PREPARATIONS, N.E.C.	22	95	345	15928
2111	CIGARETTES	27	98	332	18654
2211	WEAVING MILLS, COTTON	72	124	396	60192
2221	WEAVING MILLS, SYNTHETIC	18	86	311	8758
2231	WEAVING, FINISHING MILLS, WOOL	57	105	339	16851
2253	KNIT OUTERWEAR MILLS	24	88	314	15121
2281	YARN MILLS, EXCEPT WOOL	13	97	340	11783
2311	MEN'S AND BOYS' SUITS AND COATS	30	90	332	10327
2321	MEN'S DRESS SHIRTS AND NIGHTWEAR	27	96	345	15848
2327	SEPARATE TROUSERS	13	80	310	7995
2328	WORK CLOTHING	18	58	244	7044
2335	DRESSES	23	85	306	9042
2341	WOMEN'S AND CHILDREN'S UNDERWEAR	27	79	308	7455
2421	SAWMILLS AND PLANING MILLS	52	111	349	31655

TABLE A-4 (CONTINUED)

SIC	INDUSTRY NAME	(1) NO.COMP.	(2) AVGRNT	(3) AVGEXP	(4) AVGPOW
2431	MILLWORK PLANTS	17	50	218	5101
2432	VENEER AND PLYWOOD PLANTS	17	71	265	10814
2511	WOOD FURNITURE, NOT UPHOLSTERED	32	76	298	8342
2512	WOOD FURNITURE, UPHOLSTERED	21	93	330	10976
2621	PAPER MILLS, EXCEPT BUILDING	134	110	373	27222
2631	PAPERBOARD MILLS	18	62	251	6137
2641	PAPER COATING AND GLAZING	33	119	394	18975
2643	BAGS, EXCEPT TEXTILE BAGS	11	108	379	51029
2653	CORRUGATED SHIPPING CONTAINERS	10	57	230	4587
2711	NEWSPAPERS	207	60	227	7257
2721	PERIODICALS	104	159	478	72816
2731	BOOKS, PUBLISHIN^ AND PRINTING	126	123	397	32934
2751	PRINTING, EXCEPT LITHOGRAPHIC	72	74	284	20814
2752	PRINTING, LITHOGRAPHIC	18	52	222	3837
2815	INTERMEDIATE COAL TAR PRODUCTS	26	101	347	12746
2818	ORGANIC CHEMICALS, N.E.C.	120	107	354	26520
2819	INORGANIC CHEMICALS, N.E.C.	134	132	395	48652
2821	PLASTICS MATERIALS AND RESINS	84	114	375	42288
2824	ORGANIC FIBERS, NONCELLULOSIC	13	97	335	11094
2834	PHARMACEUTICAL PREPARATIONS	105	114	381	28107
2841	SOAP AND OTHER DETERGENTS	28	110	357	52231
2842	POLISHES AND SANITATION GOODS	20	92	345	8391
2844	TOILET PREPARATIONS	71	152	488	21582
2851	PAINTS AND ALLIED PRODUCTS	67	78	288	11836
2871	FERTILIZERS	12	116	389	46801
2899	CHEMICAL PREPARATIONS, N.E.C.	33	79	290	13574
2911	PETROLIUM REFINING	129	153	455	94760
3011	TIRES AND INNER TUBES	109	120	393	46826
3069	RUBBER PRODUCTS, N.E.C.	52	80	305	10841
3079	PLASTICS PRODUCTS, N.E.C.	58	76	280	9246

TABLE A-4 (CONTINUED)

SIC	INDUSTRY NAME	(1) NO.COMP.	(2) AVGRNT	(3) AVGEXP	(4) AVGPOW
3141	SHOES, EXCEPT RUBBER	64	102	355	16369
3221	GLASS CONTAINERS	22	141	436	45634
3241	CEMENT, HYDRAULIC	31	58	238	8884
3291	ABRASIVE PRODUCTS	11	99	333	24146
3312	BLAST FURNACES AND STEEL MILLS	353	131	416	30872
3317	STEEL PIPE AND TUBE	10	63	256	6436
3321	GRAY IRON FOUNDRIES	39	91	314	15774
3323	STEEL FOUNDRIES	25	93	331	18015
3351	COPPER ROLLING AND DRAWING	27	81	293	52633
3352	ALUMINUM ROLLING AND DRAWING	16	111	361	9702
3356	ROLLING AND DRAWING, N.E.C.	16	101	362	8973
3357	NONFERROUS WIRE DRAWING, ETC.	28	103	360	16885
3391	IRON AND STEEL FORGINGS	33	60	246	10142
3411	METAL CANS	27	105	364	65079
3429	HARDWARE, N.E.C.	39	93	331	12008
3433	HEATING EQUIPMENT, EXCEPT ELECTRIC	50	85	312	13350
3441	FABRICATED STRUCTURAL STEEL	42	57	235	9255
3442	METAL DOOR, SASH, AND TRIM	22	45	195	6014
3443	BOILER SHOP PRODUCTS	43	67	262	55872
3452	BOLTS, NUTS, RIVETS AND WASHERS	30	92	341	8216
3461	METAL STAMPINGS	55	94	331	17032
3481	FABRICATED METAL PRODUCTS, N.E.C.	16	79	295	50652
3494	VALVES AND PIPE FITTINGS	49	115	379	15529
3519	INTERNAL COMBUSTION ENGINES	58	144	441	70865
3522	FARM MACHINERY AND EQUIPMENT	166	120	384	58892
3531	CONSTRUCTION MACHINERY	63	112	383	14302
3541	METAL-CUTTING MACHINE TOOLS	64	102	356	19598
3544	SPECIAL DIES AND TOOLS	21	62	254	12268
3545	MACHINE TOOLS AND ACCESSORIES	17	82	296	9279
3548	METALWORKING MACHINERY, N.E.C.	26	89	312	14362

TABLE A-4 (CONTINUED)

SIC	INDUSTRY NAME	(1) NO.COMP.	(2) AVGRNT	(3) AVGEXP	(4) AVGPOW
3559	SPECIAL INDUSTRY MACHINERY, N.E.C.	44	96	337	23472
3561	PUMPS AND COMPRESSORS	32	103	361	24504
3562	BALL AND ROLLER BEARINGS	45	85	317	31260
3566	POWER TRANSMISSION EQUIPMENT	51	102	342	35197
3569	GENERAL INDUSTRY MACHINES, N.E.C.	43	272	556	335691
3585	REFRIGERATION MACHINERY	48	95	331	26051
3599	MISC. MACHINERY	23	87	318	11102
3611	ELECTRIC MEASURING INSTRUMENTS	111	96	329	16755
3612	TRANSFORMERS	40	109	346	51864
3613	SWITCHGEAR AND SWITCHBOARDS	41	110	369	19160
3621	MOTORS AND GENERATORS	141	131	412	37088
3622	INDUSTRIAL CONTROLS	42	144	441	43468
3634	ELECTRIC HOUSEWARES AND FANS	43	149	448	28998
3642	LIGHTING FIXTURES	19	100	353	11011
3651	RADIO AND TV RECEIVING SETS	97	138	439	96411
3661	TELEPHONE, TELEGRAPH APPARATUS	159	138	427	47464
3662	RADIO, TV COMMUNICATIONS EQUIPMENT	214	155	436	136262
3674	SEMICONDUCTORS	73	79	303	46231
3679	ELECTRONIC COMPONENTS, N.E.C.	158	145	403	85634
3694	ENGINE ELECTRICAL EQUIPMENT	13	110	372	14463
3717	MOTOR VEHICLES AND PARTS	483	134	415	51229
3721	AIRCRAFT	455	270	652	269132
3722	AIRCRAFT ENGINES AND PARTS	80	182	515	92040
3729	AIRCRAFT EQUIPMENT, N.E.C.	127	231	556	172381
3731	SHIP BUILDING AND REPAIRING	28	68	270	27049
3742	RAILROAD AND STREET CARS	15	80	270	10812
3821	MECHANICAL MEASURING DEVICES	54	87	317	14718
3861	PHOTOGRAPHIC EQUIPMENT	67	138	413	58821
3941	GAMES AND TOYS	30	80	302	10335

TABLE A-4 (CONTINUED)

EXPLANATION OF COLUMNS

(1) Number of computers in operation within this industry.

(2) Average rent of computers in industry

(3) Average total expenses of computer installations in this industry (based upon Federal Government experience)

(4) Average power of computers in industry (based upon Knight's power indecies)

TABLE A-5
FEDERAL GOVERNMENT COMPUTER RENTAL DATA

COMPUTER MANUF	MODEL	NO. INST	RENT IN DOLLARS MIN	MEAN	MAX
ASI	210	3	1194	2512	4175
ASI	2100	2	3200	5232	7264
ASI	6020	2	5410	6548	7687
ASI	6050	3	6384	7006	8028
ASI	6130	1	6855	6855	6855
AUT	REC2	18	1	869	2495
BRA	130	1	3129	3129	3129
BRA	133	4	196	2974	4500
BRA	340	1	9422	9422	9422
BUR	B250	2	4380	4380	4380
BUR	B2500	1	8910	8910	8910
BUR	B263	101	1220	2579	3700
BUR	B280	2	3833	3834	3835
BUR	B283	6	6135	7438	10895
BUR	B300	2	4168	5521	6875
BUR	B3500	77	4139	4543	35280
BUR	B5500	9	19817	37347	84063
BUR	E101	3	935	1205	1635
BUR	220	1	28220	28220	28220
CDC	G15D	30	280	1533	2621
CDC	LGP21	3	740	885	1080
CDC	LGP30	11	350	1502	5080
CDC	160	54	1600	7777	37123
CDC	160A	42	1502	9126	76709
CDC	160G	32	6025	12012	19950
CDC	1604	23	3829	35548	54590
CDC	1700	11	2070	5195	10322
CDC	3100	29	4125	11665	21302
CDC	3200	23	4340	16889	32395
CDC	3300	18	13800	30637	50780
CDC	3400	1	28350	28350	28350
CDC	3600	13	15600	57468	104292
CDC	3800	14	16200	51970	77710
CDC	4000	3	1865	2381	3150
CDC	4010	1	2530	2530	2530
CDC	6400	7	38700	61221	81655
CDC	6600	27	62950	111848	328505
CDC	8041	1	2955	2955	2955
CDC	8090	37	1650	4642	16900
CDC	8092B	5	3915	4207	4835
CDC	8490	2	5230	5922	6615
CDC	924	14	4352	16535	24186
CDC	924A	3	10262	16792	21015
DEQ	LINC8	5	160	1272	3954
DEQ	PDP1	14	1327	4418	10682

TABLE A-5 (CONTINUED)

COMPUTER MANUF	MODEL	NO. INST	RENT IN DOLLARS MIN	MEAN	MAX
DEQ	PDP10	1	12650	12650	12650
DEQ	PDP4	6	1750	2823	4732
DEQ	PDP5	15	400	1134	3038
DEQ	PDP6	2	2492	3871	5250
DEQ	PDP7	9	1240	2767	3672
DEQ	PDP8	16	142	431	1069
DEQ	PDP8S	4	199	241	294
DEQ	PDP9	5	1024	1897	3834
EAI	8400	1	9088	9088	9088
ELT	ALW3	2	110	1855	3600
FRI	6010	6	621	1190	1820
GEL	D30	1	6913	6913	6913
GEL	PAC402	4	35270	37457	39791
GEL	115	4	3005	4375	6880
GEL	205	5	2625	3445	5400
GEL	215	4	3163	4805	7510
GEL	225	22	1835	8858	13763
GEL	235	8	11258	24597	58025
GEL	412	5	4904	5298	5662
GEL	415	4	9740	12929	16150
GEL	425	5	9140	17338	20593
GEL	435	6	22645	23873	24251
GEL	625	1	43850	43850	43850
GEL	635	4	32733	73358	100740
HON	DDP116	13	243	2396	5162
HON	DDP19	1	4724	4724	4724
HON	DDP124	4	2750	4237	7050
HON	DDP224	25	4500	9723	17426
HON	DDP24	20	1809	6142	11197
HON	DDP416	2	378	489	600
HON	DDP516	11	478	1747	3891
HON	H620	1	5400	5400	5400
HON	H632	1	6000	6000	6000
HON	120	9	2360	3925	4955
HON	1200	30	5305	10375	15165
HON	1800	3	39850	44792	50437
HON	200	89	2300	7541	22599
HON	2200	13	11190	16453	27826
HON	400	6	4785	11273	14445
HON	610	1	6060	6060	6060
HON	800	21	13033	20915	50248
IBM	1130	75	770	1658	3037
IBM	1401	356	1136	6797	22775
IBM	1410	72	9600	26175	58406
IBM	1440	22	2750	5838	13979

TABLE A-5 (CONTINUED)

COMPUTER MANUF	COMPUTER MODEL	NO. INST	RENT IN DOLLARS MIN	RENT IN DOLLARS MEAN	RENT IN DOLLARS MAX
IBM	1460	25	7140	11910	19271
IBM	1500	2	12248	19821	27395
IBM	1620	69	1164	3428	6891
IBM	1710	1	16158	16158	16158
IBM	1800	22	1220	4918	11020
IBM	305	2	4012	4012	4012
IBM	36020	72	617	2916	7576
IBM	36030	117	3990	12127	28225
IBM	36040	70	8068	23404	51337
IBM	36044	8	5666	10675	20169
IBM	36050	55	14165	37564	95442
IBM	36065	33	13905	58219	161266
IBM	36067	4	57405	98931	171303
IBM	36075	13	63696	106248	143028
IBM	36091	2	129395	150300	171206
IBM	36095	2	138236	141443	144651
IBM	610	1	1150	1150	1150
IBM	6400	3	730	931	1054
IBM	650	1	4450	4450	4450
IBM	7010	15	30523	45657	77036
IBM	7030	3	118075	142950	177200
IBM	704	3	10674	20363	38272
IBM	7040	13	12259	37532	68924
IBM	7044	12	33750	62534	129389
IBM	705	4	22800	32502	45100
IBM	7070	2	18220	28679	39139
IBM	7074	15	25120	47427	109576
IBM	7080	33	49548	77287	140554
IBM	7090	17	43561	76040	103309
IBM	7094	46	35967	76932	122284
IBM	709411	7	51704	84376	116935
IBM	7740	7	6733	11096	16137
IBM	9020	4	11779	26101	48586
INF	4900	1	700	700	700
ITT	ADX73	3	493	42086	106133
NCR	304	4	15390	16778	18708
NCR	315	11	7225	10207	17965
NCR	390	135	534	1765	2062
NCR	500	36	1015	1533	1920
PDS	1020	4	450	601	900
PHI	1000	4	5100	16759	25598
PHI	2000	6	23970	52773	89928
RAY	250	24	460	1135	1766
RAY	440	2	5228	5743	6259
RAY	440	2	5228	5743	6259

TABLE A-5 (CONTINUED)

COMPUTER MANUF	MODEL	NO. INST	RENT IN DOLLARS MIN	MEAN	MAX
RAY	520	5	2191	4900	8154
RCA	301	106	4403	10887	25065
RCA	3301	25	17923	28648	46562
RCA	4101	1	4000	4000	4000
RCA	501	25	5240	19242	41111
RCA	7025	1	7610	7610	7610
RCA	7035	14	10425	11325	14558
RCA	7045	6	12373	19601	22991
SCC	650	3	433	634	950
SCC	660	2	1800	2114	2428
SDS	SIGMA2	5	1310	2171	4029
SDS	SIGMA5	3	1385	8796	20030
SDS	SIGMA7	7	3885	8720	18577
SDS	910	53	521	4371	19566
SDS	92	4	2760	6235	13359
SDS	920	52	1800	5563	11660
SDS	925	3	3480	5309	8673
SDS	930	48	1605	8255	20600
SDS	9300	7	9655	13433	18233
SDS	940	1	28009	28009	28009
SEL	810	7	640	6380	8020
SEL	810A	2	1350	1707	2065
SEL	810B	2	1335	1657	1980
SEL	840	4	1232	1863	3390
SEL	840A	2	4584	4750	4916
SEL	840MP	2	1	1	1
UNI	FCII	3	23770	24380	25426
UNI	II	1	15174	15174	15174
UNI	III	8	19520	22131	26225
UNI	M460	1	9032	9032	9032
UNI	SS80	5	5750	12647	26320
UNI	SS90	2	6865	7032	7200
UNI	1004	196	535	2380	4772
UNI	1004II	14	1055	2836	3485
UNI	1005	148	1297	1951	4452
UNI	1005II	2	2993	3024	3055
UNI	1005IV	2	1975	2030	2085
UNI	1050	122	1950	9134	16000
UNI	1050A	1	5052	5052	5052
UNI	1050II	6	6400	8398	10135
UNI	1105	1	48060	48060	48060
UNI	1107	9	56395	68440	74603
UNI	1108	30	14100	47449	214791
UNI	1218	22	1606	4680	11352
UNI	1219	7	3720	12599	28360

TABLE A-5 (CONTINUED)

COMPUTER MANUF	MODEL	NO. INST	RENT IN DOLLARS MIN	MEAN	MAX
UNI	1230	7	0	7012	19238
UNI	1500	1	2404	2404	2404
UNI	418	30	4555	11129	26573
UNI	490	9	25050	50295	99070
UNI	492	1	44249	44249	44249
UNI	494	17	10500	50508	112718
UNI	642A	6	1100	6366	13414
UNI	642B	7	8425	13726	20494
UNI	667	1	37202	37202	37202
UNI	818	1	7166	7166	7166
UNI	855	3	6120	7556	8274
UNI	9200	2	1160	1352	1545
UNI	9300	17	1580	2203	10500
WES	DDS240	1	9	9	9

TABLE A-6
COMPUTER APPLICATIONS BY INDUSTRY
(PERCENT IN EACH CATEGORY)

SIC	INDUSTRY NAME	(1) NCOMP	(2) NAPP	APPLICATIONS BUSI	ANAL	PROC
2011	MEAT SLAUGHTERING PLANTS	106	74	95	0	4
2013	MEAT PROCESSING PLANTS	27	23	100	0	0
2023	CONDENSED AND EVAPORATED MILK	19	13	92	0	7
2024	ICE CREAM AND FROZEN DESSERTS	33	28	96	0	3
2026	FLUID MILK	39	30	100	0	0
2032	CANNED SPECIALTIES	19	13	100	0	0
2033	CANNED FRUITS AND VEGETABLES	65	51	100	0	0
2037	FROZEN FRUITS AND VEGETABLES	31	26	92	3	3
2041	FLOUR MILLS	34	26	92	3	3
2042	PREPARED ANIMAL FEEDS	41	27	100	0	0
2051	BREAD AND RELATED PRODUCTS	45	35	82	2	14
2052	BISCUITS, CRACKERS, AND COOKIES	16	13	92	0	7
2071	CONFECTIONARY PRODUCTS	33	29	93	0	6
2082	MALT LIQUOR	40	32	93	3	3
2085	DISTILLED LIQUOR, EXCEPT BRANDY	29	20	100	0	0
2086	BOTTLED AND CANNED SOFT DRINKS	27	24	100	0	0
2099	FOOD PREPARATIONS, N.E.C.	22	18	94	5	0
2111	CIGARETTES	27	20	95	0	5
2211	WEAVING MILLS, COTTON	72	57	70	8	21
2221	WEAVING MILLS, SYNTHETIC	18	15	80	0	20
2231	WEAVING, FINISHING MILLS, WOOL	57	42	88	2	9
2253	KNIT OUTERWEAR MILLS	24	23	86	13	0
2281	YARN MILLS, EXCEPT WOOL	13	11	81	9	9
2311	MEN'S AND BOYS' SUITS AND COATS	30	24	66	0	33
2321	MEN'S DRESS SHIRTS AND NIGHTWEAR	27	19	100	0	0
2327	SEPARATE TROUSERS	13	11	100	0	0
2328	WORK CLOTHING	18	15	86	0	13
2335	DRESSES	23	19	94	0	5
2341	WOMEN'S AND CHILDREN'S UNDERWEAR	27	23	86	0	13
2421	SAWMILLS AND PLANING MILLS	52	39	100	0	0

TABLE A-6 (CONTINUED)

SIC	INDUSTRY NAME	(1) NCOMP	(2) NAPP	APPLICATIONS BUSI	ANAL	PROC
2431	MILLWORK PLANTS	17	15	86	0	13
2432	VENEER AND PLYWOOD PLANTS	17	10	100	0	0
2511	WOOD FURNITURE, NOT UPHOLSTERED	32	26	88	0	11
2512	WOOD FURNITURE, UPHOLSTERED	21	16	87	0	12
2621	PAPER MILLS, EXCEPT BUILDING	134	102	82	2	14
2631	PAPERBOARD MILLS	18	17	76	0	23
2641	PAPER COATING AND GLAZING	33	26	57	34	7
2643	BAGS, EXCEPT TEXTILE BAGS	11	6	100	0	0
2653	CORRUGATED SHIPPING CONTAINERS	10	9	88	0	11
2711	NEWSPAPERS	207	176	60	1	38
2721	PERIODICALS	104	81	67	0	32
2731	BOOKS, PUBLISHING AND PRINTING	126	90	87	3	8
2751	PRINTING, EXCEPT LITHOGRAPHIC	72	58	81	1	17
2752	PRINTING, LITHOGRAPHIC	18	17	94	0	5
2815	INTERMEDIATE COAL TAR PRODUCTS	26	18	72	11	16
2818	ORGANIC CHEMICALS, N.E.C.	120	54	62	20	16
2819	INORGANIC CHEMICALS, N.E.C.	134	76	75	25	0
2821	PLASTICS MATERIALS AND RESINS	84	58	89	10	0
2824	ORGANIC FIBERS, NONCELLULOSIC	13	10	70	30	0
2834	PHARMACEUTICAL PREPARATIONS	105	73	83	15	1
2841	SOAP AND OTHER DETERGENTS	28	24	95	0	4
2842	POLISHES AND SANITATION GOODS	20	17	94	0	5
2844	TOILET PREPARATIONS	71	58	100	0	0
2851	PAINTS AND ALLIED PRODUCTS	67	53	88	7	3
2871	FERTILIZERS	12	10	90	10	0
2899	CHEMICAL PREPARATIONS, N.E.C.	33	22	72	18	9
2911	PETROLIUM REFINING	129	64	67	29	3
3011	TIRES AND INNER TUBES	109	81	88	4	6
3069	RUBBER PRODUCTS, N.E.C.	52	38	89	0	10
3079	PLASTICS PRODUCTS, N.E.C.	53	49	87	2	10

TABLE A-6 (CONTINUED)

SIC	INDUSTRY NAME	(1) NCOMP	(2) NAPP	APPLICATIONS BUSI	ANAL	PROC
3141	SHOES, EXCEPT RUBBER	64	47	85	0	14
3221	GLASS CONTAINERS	22	13	76	0	23
3241	CEMENT, HYDRAULIC	31	28	71	7	21
3291	ABRASIVE PRODUCTS	11	8	87	0	12
3312	BLAST FURNACES AND STEEL MILLS	353	166	67	4	28
3317	STEEL PIPE AND TUBE	10	9	77	0	22
3321	GRAY IRON FOUNDRIES	39	26	76	11	11
3323	STEEL FOUNDRIES	25	16	81	6	12
3351	COPPER ROLLING AND DRAWING	27	27	77	0	22
3352	ALUMINUM ROLLING AND DRAWING	16	13	61	0	38
3356	ROLLING AND DRAWING, N.E.C.	16	14	71	14	14
3357	NONFERROUS WIRE DRAWING, ETC.	28	25	76	4	20
3391	IRON AND STEEL FORGINGS	33	22	90	0	9
3411	METAL CANS	27	13	84	7	7
3429	HARDWARE, N.E.C.	39	31	64	0	35
3433	HEATING EQUIPMENT, EXCEPT ELECTRIC	50	33	72	6	21
3441	FABRICATED STRUCTURAL STEEL	42	35	74	14	11
3442	METAL DOOR, SASH, AND TRIM	22	21	57	14	28
3443	BOILER SHOP PRODUCTS	43	37	59	29	10
3452	BOLTS, NUTS, RIVETS AND WASHERS	30	27	85	3	11
3461	METAL STAMPINGS	55	45	80	0	20
3481	FABRICATED METAL PRODUCTS, N.E.C.	16	12	83	8	8
3494	VALVES AND PIPE FITTINGS	49	40	82	5	12
3519	INTERNAL COMBUSTION ENGINES	58	41	65	14	19
3522	FARM MACHINERY AND EQUIPMENT	166	104	75	5	19
3531	CONSTRUCTION MACHINERY	63	46	78	0	21
3541	METAL-CUTTING MACHINE TOOLS	64	52	63	11	25
3544	SPECIAL DIES AND TOOLS	21	16	87	6	6
3545	MACHINE TOOLS AND ACCESSORIES	17	16	93	0	6
3548	METALWORKING MACHINERY, N.E.C.	26	23	86	8	4

TABLE A-6 (CONTINUED)

SIC	INDUSTRY NAME	(1) NCOMP	(2) NAPP	APPLICATIONS BUSI	APPLICATIONS ANAL	APPLICATIONS PROC
3559	SPECIAL INDUSTRY MACHINERY, N.E.C.	44	37	56	16	27
3561	PUMPS AND COMPRESSORS	32	25	68	8	24
3562	BALL AND ROLLER BEARINGS	45	31	51	6	41
3566	POWER TRANSMISSION EQUIPMENT	51	39	84	2	12
3569	GENERAL INDUSTRY MACHINES, N.E.C.	43	29	65	27	6
3585	REFRIGERATION MACHINERY	48	31	87	0	12
3599	MISC. MACHINERY	23	21	66	14	19
3611	ELECTRIC MEASURING INSTRUMENTS	111	92	46	22	30
3612	TRANSFORMERS	40	30	60	20	20
3613	SWITCHGEAR AND SWITCHBOARDS	41	36	72	13	13
3621	MOTORS AND GENERATORS	141	107	61	25	13
3622	INDUSTRIAL CONTROLS	42	29	65	17	17
3634	ELECTRIC HOUSEWARES AND FANS	43	34	64	8	26
3642	LIGHTING FIXTURES	19	19	84	0	15
3651	RADIO AND TV RECEIVING SETS	97	75	84	2	13
3661	TELEPHONE, TELEGRAPH APPARATUS	159	79	72	10	17
3662	RADIO, TV COMMUNICATIONS EQUIPMENT	214	152	60	29	9
3674	SEMICONDUCTORS	73	22	31	54	13
3679	ELECTRONIC COMPONENTS, N.E.C.	158	125	48	36	15
3694	ENGINE ELECTRICAL EQUIPMENT	13	11	81	9	9
3717	MOTOR VEHICLES AND PARTS	443	267	74	9	15
3721	AIRCRAFT	455	191	47	45	7
3722	AIRCRAFT ENGINES AND PARTS	80	39	46	46	7
3729	AIRCRAFT EQUIPMENT, N.E.C.	127	99	37	39	23
3731	SHIP BUILDING AND REPAIRING	28	24	91	8	0
3742	RAILROAD AND STREET CARS	15	10	60	10	30
3821	MECHANICAL MEASURING DEVICES	54	41	78	4	17
3861	PHOTOGRAPHIC EQUIPMENT	67	36	77	11	11
3941	GAMES AND TOYS	30	28	89	0	10

TABLE A-6 (CONTINUED)
EXPLANATION OF COLUMNS

(1) NCOMP - Number of computers in industry

(2) NAPP - Number of computers in industry that reported principal application area

BIOGRAPHICAL NOTE

Lee Lawrence Selwyn was born in New York City on June 16, 1942. He received his primary and secondary education in New York and won a New York State Regents Scholarship upon graduation from high school in 1958.

Mr. Selwyn attended Queens College in Flushing, New York, and graduated with a Bachelor of Arts degree in 1962. At Queens he was elected to membership in two honor societies, Omicron Delta Epsilon (Economics) and Pi Sigma Alpha (Political Science). He graduated with departmental honors in Economics.

Mr. Selwyn was admitted to the Sloan School of Management at the Massachusetts Institute of Technology in 1962, where he pursued a Master of Science degree, which was received in 1964, and subsequently the doctorate. At MIT, Mr. Selwyn was the recipient of an IBM Research Assistantship, a United States Steel Foundation Doctoral Fellowship, and a Dissertation Grant-in-Aid from the National Association of Accountants. He was a Research Assistant at Project MAC at MIT from 1963 until 1969, and was also a Teaching Assistant at the Sloan School during the period 1964 - 1966.

He has published several articles, including "The Information Utility," in the Industrial Management Review

(Spring, 1966); "Taxes, Corporate Financial Policy and Return to Investors," with D. E. Farrar, in the National Tax Journal (December 1967); "Considerations for Computer Utility Pricing Policies," with D. S. Diamond, presented at the 1968 National Conference of the Association for Computing Machinery; and "Real-Time Computer Communications and the Public Interest," with M. M. Gold, presented at the 1968 Fall Joint Computer Conference.

During 1967-68 he served as a consultant to the Business Equipment Manufacturers Association and participated in the preparation of that organization's response to the Federal Communications Commission's "Computer Inquiry." Mr. Selwyn is presently Assistant Professor of Finance at the Boston University College of Business Administration.

Mr. Selwyn lives in Chestnut Hill, Massachusetts, with his wife, Judith, and son, Mark.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Massachusetts Institute of Technology Project MAC	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP None

3. REPORT TITLE

Economies of Scale in Computer Use: Initial Tests and Implications for the Computer Utility

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Ph.D. Thesis, Alfred P. Sloan School of Management, June, 1969

5. AUTHOR(S) *(Last name, first name, initial)*

Selwyn, Lee L.

6. REPORT DATE June 1969	7a. TOTAL NO. OF PAGES 116	7b. NO. OF REFS 10
8a. CONTRACT OR GRANT NO. ONR, Nonr-4102(01) b. PROJECT NO. NR-048-189 c. d. RR 003-09-01	9a. ORIGINATOR'S REPORT NUMBER(S) MAC TR-68 (THESIS) 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency 3D-200 Pentagon Washington, D.C. 20301

13. ABSTRACT This study is concerned with the existence of economies of scale in the production of data processing and other computing services, and the possible regulatory and public policy implications of such economies.

. . . an analysis was made of data on nearly 10,000 computers installed at firms in manufacturing industries, using the survival technique, which uses market experience as a basis for studying levels of optimum plant size. The results of this analysis suggested that users did operate computers as if there were significant economies of scale in their use.

. . . This is at least as much a technological problem as it is regulatory; the future of the computer utility concept will thus be dependent upon the degree to which technology can reduce costs in these categories.

14. KEY WORDS Computers. Computer utility. Economics. Time sharing. Time-sharing computers. Industry installations.

DD FORM 1 NOV 65 1473 (M.I.T.)

UNCLASSIFIED

Security Classification